



CORE CAPACITY CONSTRAINTS

Accommodating Growth on Greater Boston's
Congested Roads and Crowded Transit Systems



Core-Capacity Constraints

Accommodating Growth on Greater Boston's Congested Roads and Crowded Transit System

Project Manager

Bruce Kaplan

Project Principal

Scott Peterson

Report Author

Bill Kuttner

Data Analysts

Brynn Leopold

Drashti Joshi

Ian Harrington

Tom Humphrey

Graphics

Ken Dumas

Jane Gillis

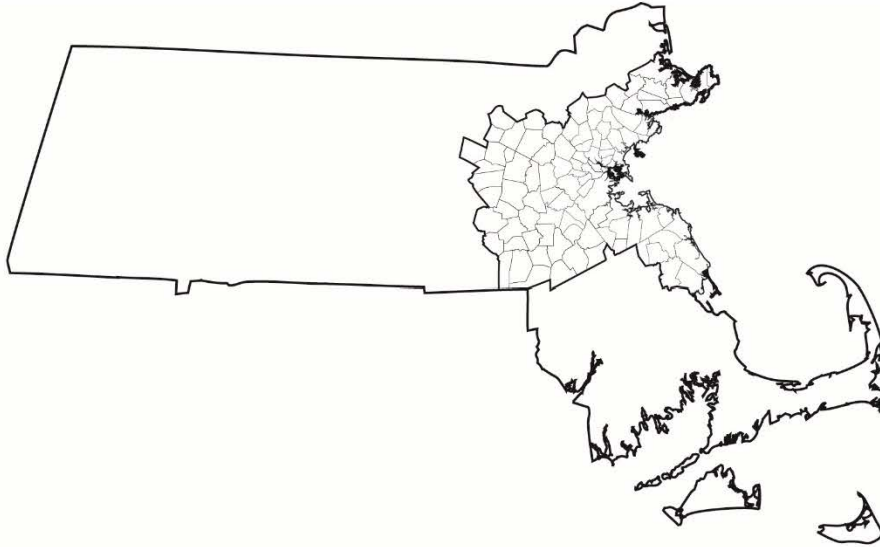
Cover Design

Kate Parker-O'Toole

The preparation of this document was supported by the Federal Highway Administration through MHD 3C PL contracts #32075 and #33101.

Central Transportation Planning Staff
Directed by the Boston Region Metropolitan Planning Organization. The MPO is composed of state and regional agencies and authorities, and local governments.

August 2016



To request additional copies of this document or
copies in an accessible format, contact:

Central Transportation Planning Staff
State Transportation Building
Ten Park Plaza, Suite 2150
Boston, Massachusetts 02116

(857) 702-3700
(617) 570-9192 (fax)
(617) 570-9193 (TTY)

ctps@ctps.org
www.bostonmpo.org

ABSTRACT

This study examines the capacity of road and transit facilities in the Boston Region Metropolitan Planning Organization's (MPO) core area. The study relates these capacities to current and projected levels of traffic and ridership, and determines the location and severity of congestion and crowding in the core area.

Travel demand is projected to increase significantly by 2040 in response to regional demographic growth and expanded economic activity in the core area. In this report, MPO staff discuss the historical and projected demographic trends that inform travel-demand projections; identify specific major developments that will contribute to this growth; and present historical trends of traffic and transit ridership.

The study relates projected 2040 travel demand to the system capacity expected to be available at that time. Where sufficient data is available, the study quantifies impacts attributable to a set of specific large developments. For some transportation modes and services, adding new capacity is straightforward and for others it is problematic. In this report, we discuss the opportunities and challenges of adding capacity for each transportation subsystem.

In Massachusetts, a major development or business expansion often requires some actions on the part of the developer or business to mitigate, in part, the impacts on the transportation system that are attributable to the project. Chapter 6 includes a review of the large variety of such mitigation programs that have been implemented in the core area. We give special attention to mitigation involving new transit investment or operating subsidies. The chapter concludes with a discussion of expanded mitigation programs that are used in other states, but which would require legislation to be implemented in Massachusetts.

TABLE OF CONTENTS	PAGE
Abstract.....	3
1 — Introduction.....	7
1.1 Background.....	7
1.2 Objectives of this Study.....	7
1.3 Report Organization.....	9
2 — Demographic and Development Trends.....	10
2.1 The Urban Core after Suburbanization.....	10
2.2 The Study Area Municipalities.....	11
2.3 Population and Employment Trends.....	11
2.4 Considering Large-Impact Development Projects.....	16
3 — Commuting and Travel Trends.....	22
3.1 Commuting by Study Area Residents.....	22
3.2 Travel Trends in the Transportation Subsystems.....	27
4 — Roadway Capacity Issues.....	31
4.1 Roadway Capacity and Congestion.....	31
4.2 Base Year and Projected Roadway Congestion.....	31
4.3 Congestion Associated with the Key Large-Impact Projects.....	33
5 — Transit Capacity Issues.....	37
5.1 Projected Rapid Transit Ridership.....	37
5.2 Measuring Capacity and Crowding on Rapid Transit Lines.....	38
5.3 Rapid Transit Capacity as it is Actually Experienced.....	42
5.4 Peak-Period Crowding on the Rail Rapid Transit Lines.....	43
5.5 Peak-Period Crowding on Bus Vehicles.....	74
5.6 Peak-Period Crowding on Commuter Rail.....	86
6 — Transportation Mitigation Policies.....	94
6.1 Broad-Based Travel Growth and Individual Developments.....	94
6.2 Mitigation Strategies and Techniques.....	95
6.3 Modifying Tax and Fee Structures.....	99
7 — Summary and Conclusions.....	104
7.1 Crowding and Congestion.....	104
7.2 Mitigation.....	105

TABLE OF FIGURES	PAGE
Figure 1 Study Area, Boston MPO Region, and Travel Demand Model Region	8
Figure 2 Regional Development Database.....	18
Figure 3 Trip Estimation Process	19
Figure 4 Representative Sample of Traffic Analysis Zones (TAZs)	21
Figure 5 Location of Large-Impact Projects and AM Congested Roadway Links.....	34
Figure 6 Location of Large-Impact Projects and PM Congested Roadway Links.....	35
Figure 7 Red Line AM Peak Crowding: Alewife to Braintree/Ashmont	46
Figure 8 Red Line PM Peak Crowding: Ashmont/Braintree to Alewife	47
Figure 9 Red Line AM Peak Crowding: Ashmont/Braintree to Alewife	48
Figure 10 Red Line PM Peak Crowding: Alewife to Braintree/Ashmont	49
Figure 11 Orange Line AM Peak Crowding: Oak Grove to Forest Hills.....	50
Figure 12 Orange Line PM Peak Crowding: Forest Hills to Oak Grove	51
Figure 13 Orange Line AM Peak Crowding: Forest Hills to Oak Grove	52
Figure 14 Orange Line PM Peak Crowding: Oak Grove to Forest Hills.....	53
Figure 15 Green Line AM Peak Crowding: Lechmere to Kenmore/Symphony.....	54
Figure 16 Green Line PM Peak Crowding: Symphony/Kenmore to Lechmere.....	55
Figure 17 Green Line AM Peak Crowding: Symphony/Kenmore to Lechmere.....	56
Figure 18 Green Line PM Peak Crowding: Lechmere to Kenmore/Symphony.....	57
Figure 19 Blue Line AM Peak Crowding: Wonderland to Bowdoin.....	58
Figure 20 Blue Line PM Peak Crowding: Bowdoin to Wonderland.....	59
Figure 21 Blue Line AM Peak Crowding: Bowdoin to Wonderland.....	60
Figure 22 Blue Line PM Peak Crowding: Wonderland to Bowdoin.....	61
Figure 23 Commuter Rail System and Locations with Crowding.....	89

TABLE OF TABLES	PAGE
Table 1 Historical and Projected Population, 1970–2040E	12
Table 2 Historical and Projected Employment, 1970–2040E	13
Table 3 Population and Employment per Square Mile, 1970–2040E	14
Table 4 Density Trends: Change in Population and Employment per Sq.Mile per Year	16
Table 5 Sample TAZ Locations	20
Table 6 Study Area Commuting Trends, 1980–2010E	22

Table 7 Study Area Mode Choice Trends, 1980–2010E	23
Table 8 Regional Commuting Trends, 1991–2011	24
Table 9 Study Area Commuting Patterns in 2011	26
Table 10 MBTA Average Weekday Ridership Trends, 1990–2013	27
Table 11 Vehicle-Miles Traveled on Limited-Access Highways, 1970–2010.....	29
Table 12 Major Roadway Congested Miles, 2012–2040E	32
Table 13 Historical and Projected Weekday Rapid Transit Ridership, 1990–2040E	37
Table 14 The Impact of Available Passenger Floor Space on Rapid Transit Service ...	39
Table 15 Passenger Capacities and Crowding on Rapid Transit Vehicles.....	40
Table 16 Total Daily Rapid Transit Capacity	41
Table 17 Base Year Bus Vehicle Crowding on Radial Routes–Peak AM Hour, 2012 ...	76
Table 18 Base Year Bus Vehicle Crowding on Radial Routes–Peak PM Hour, 2012 ...	77
Table 19 Base Year Bus Vehicle Crowding on Non-Radial Routes– Peak AM Hour	78
Table 20 Base Year Bus Vehicle Crowding on Non-Radial Routes– Peak PM Hour	78
Table 21 Year 2040 Bus Vehicle Crowding on Radial Route–Peak AM Hour	82
Table 22 Year 2040 Bus Vehicle Crowding on Radial Route–Peak PM Hour	83
Table 23 Year 2040 Bus Vehicle Crowding on Non-Radial Routes–Peak AM Hour	84
Table 24 Year 2040 Bus Vehicle Crowding on Non-Radial Routes–Peak PM Hour	84
Table 25 Crowding on Most-Heavily Used Inbound Commuter Trains, 2012.....	88
Table 26 Crowding on Most-Heavily Used Outbound Commuter Trains, 2012	91

Chapter 1—Introduction

1.1 Background

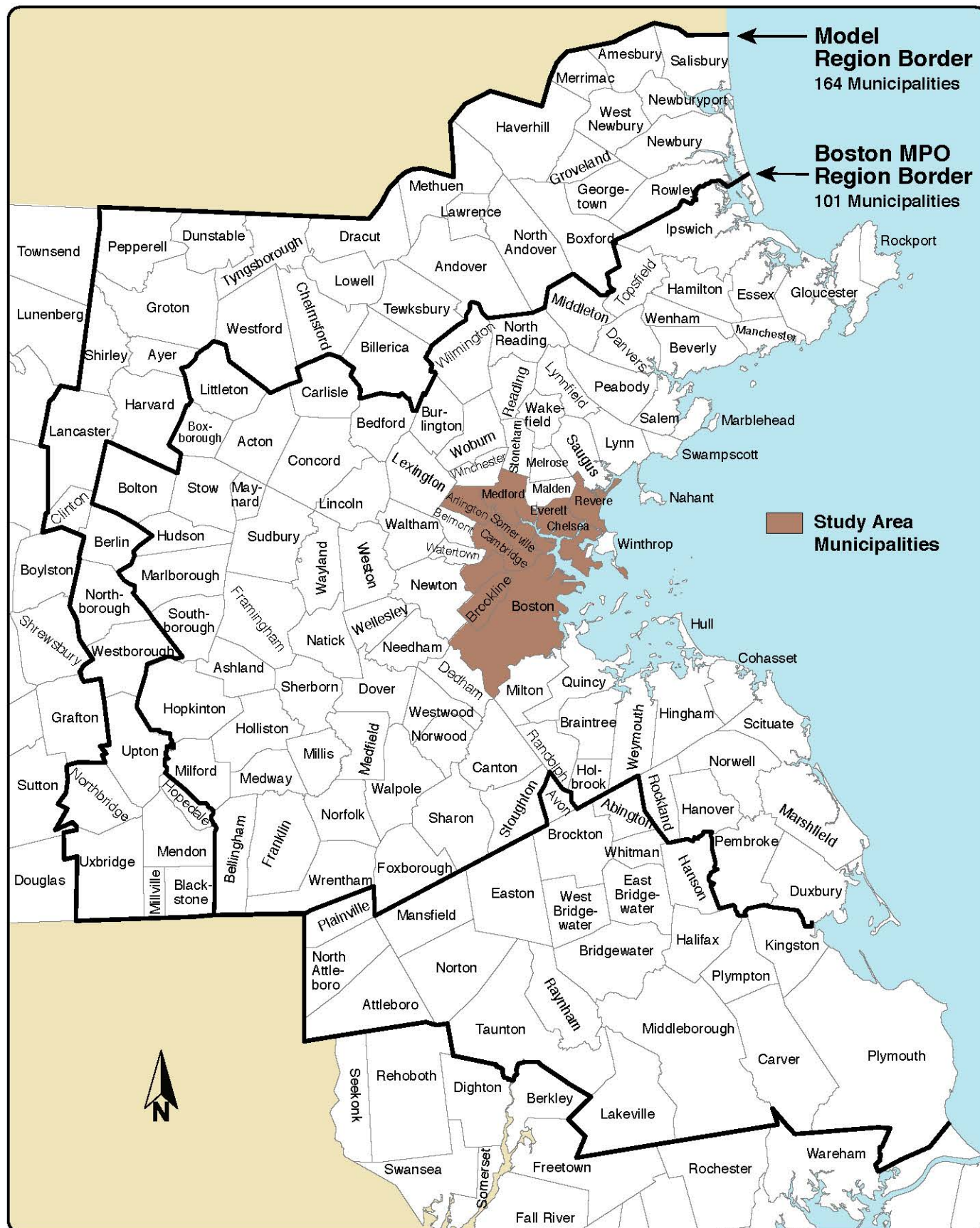
At any particular point in time, the capacity of a region's transportation system may be considered as fixed. The various parts of a roadway network can only carry a certain number of vehicles, and these maximum traffic levels are reached on important parts of the system during peak periods each day. Similarly, the fixed-guideway transit systems—commuter rail, rapid transit, and underground busway—have a maximum number of vehicles that can operate safely on each part of the system at any given time.

It is possible to increase the carrying capacities of transportation system elements by improving efficiency or constructing additional physical capacity. Efficiency improvements tend to be incremental, and adding physical capacity generally is a long-term strategy. For public transportation, there is a medium-term strategy: expanding the capacity of the transit vehicle fleet by either increasing the number of vehicles or replacing existing vehicles with larger ones.

The adequacy of transportation capacity in a metropolitan region has important ramifications for the region's economic health and quality of life, both in the present and the future. Capacity and utilization of the Boston Region MPO's transportation system are the subjects of this study. The central part, or "core," of the Boston Region MPO area is densely developed, and a great deal of regional travel either begins, ends, or passes through the core-area municipalities, which are the focus of this study. Figure 1 shows the 101-municipality Boston Region MPO area, the nine study-area municipalities, and the 164-municipality travel demand model region that staff uses to estimate travel in the MPO region.

1.2 Objectives of this Study

The purpose of this study is to analyze travel demand, available capacity, and associated congestion in the key transportation subsystems serving Boston's core area, with the goal of finding opportunities to increase the capacity of each subsystem. Staff began with the 2012 Base-Year travel demand, and projected it to 2040, while estimating crowding and congestion expected in the year 2040.



BOSTON
REGION
MPO

Figure 1
Study Area, 101-Municipality Boston MPO Region,
and 164-Municipality Travel Demand Model Region

Core
Capacity
Constraints

We used an analysis of historical and projected population and employment trends as a context for the crowding and congestion analyses. Staff projected significant demographic growth and associated new travel demand within the study area and the rest of the metropolitan region. Much of this anticipated growth is based on a set of specific large projects; the crowding and congestion attributed to this group of specific projects represents an important finding of this study. We have estimated the transportation impacts of these projects as a group for each mode and submode, where possible.

A third set of findings relates to the scope and nature of mitigation arrangements between developers and municipalities, or operating agencies, in the study area. There are legal and practical limits to mitigation in Massachusetts, which staff contrasted with mitigation options that are available in other states.

1.3 Report Organization

The report begins by providing the demographic and land use context for the study. We present historical and projected population and employment trends, and analyze regional land use patterns and trends by using density calculations. Staff used an extensive regional land use database to identify a set of specific large development projects, mentioned above, whose collective transportation impacts are estimated in later sections.

Chapter 3 reviews historical transportation trends. Transportation trends with a reliable historical record include numbers of commuters, commuting mode choice, average commute distance, total transit ridership by submode, and total vehicle-miles traveled on limited-access highways.

The next two chapters analyze Base Year and 2040 congestion and crowding in the study area's roadway network and major transit submodes: rapid transit, bus vehicle service, and commuter rail. Staff developed distinct metrics for each mode based upon data availability and operational characteristics. For the roadway network and the four rapid transit lines, sufficient data were available to allow staff to estimate the combined transportation impact of the selected large-impact developments.

The study concludes with an analysis of current and potential mitigation practices. Some of the most significant mitigation arrangements in the study area are profiled in Chapter 6, and a thorough compilation of study-area mitigation practices is included in an appendix.

Chapter 2—Demographic and Development Trends

2.1 The Urban Core after Suburbanization

In the United States, suburbanization was largely the dominant developmental pattern of the previous century. Population grew more rapidly in the less developed areas surrounding densely populated city centers. In many places, the population in city centers actually declined. This pattern of slower growth or possibly decline in city centers also was reflected in employment trends.

Even during periods of economic difficulty, the central core of a metropolitan region generally contains important transportation hubs upon which regional travel and commerce depend. Given the central location of these facilities, there always is congestion and physical wear on core-area infrastructure because of regional travel, even without strong core-area growth.

Demographic and economic growth continues to increase the demands placed upon US regional transportation systems. While growth continues in the nation's suburbs, its dense urban core areas currently are growing faster than they had in the past.

One implication of revitalized growth in the urban core is that the resulting incremental transportation burdens are perceived differently by the public and policymakers than they were when suburban development was prevalent. Earlier suburban developments often were undertaken at locations where traffic congestion was not considered a major issue. But, over time, lengthy travel to and from these developments added to regional traffic, which, combined with travel generated by other suburban developments, has resulted in the pervasive regional congestion we see today.

In contrast, most new developments in urban core areas are constructed at locations where congestion already may be a problem—for roadways, transit services, or both. While some of this traffic is generated locally, a significant amount of regional traffic funnels through many urban core locations.

New development in urban cores is not spread uniformly across core-area municipalities. In addition, sometimes an area viewed as a major development is, in fact, a group of smaller, closely located developments that are proceeding on similar schedules. These project clusters can represent a variety of activities and land uses. The re-use of large tracts of previously industrial land can result in a large development cluster. Removing existing structures, such as parking garages, also can create opportunities for large-scale development.

An important goal of this study is to quantify the transportation impacts of a sample of planned large-impact urban core development projects. While the sample projects all contain major transportation impacts, they should be considered in the context of historical growth trends, projected 2040 conditions, and the overall development underlying these trends.

2.2 Study-Area Municipalities

Even with the intense appetite for building up the urban core, significant development still is underway throughout the Boston Region MPO area. All envisioned regional development affects availability of core-area transportation capacity to some extent, and all regional development is reflected in the planning forecasts presented in this study. For the purpose of this study, however, we have selected a group of municipalities that constitutes the formal study area.

In addition to Boston, eight adjacent or nearby municipalities agreed to cooperate in this study, and shared detailed planning and mitigation programs as part of a project-working group. These municipalities are Arlington, Boston, Brookline, Cambridge, Chelsea, Everett, Medford, Revere, and Somerville (see Figure 1).

2.3 Population and Employment Trends

Population

Table 1 cites the region's population trends from 1970 to 2040 (estimated), which are significant for their direction, not for their magnitude. Between 1970 and 1980, every area listed in the table lost population. Between 1980 and 1990, four study-area municipalities were growing, and the entire study area added population. Population growth in the study area accelerated after 1990, but by 2010 had not yet returned to its 1970 level.

Several factors contributed to this population decline. Since the 1950s, many first-time homebuyers viewed the auto-oriented suburbs as more desirable than the older, dense cities. In the 1970s, regional economics exacerbated this trend. In addition, many residents of Boston and its suburbs moved to distant sun-belt locations.

Another important trend during this period is the gradual decrease over the last few decades in average household size nationwide. This trend contributes to population decline in many municipalities, especially those with little new-housing starts. Many parents choose to stay in their ample homes even after grown children move out. Unless the property is sold to another, larger family, the population can decline. As perceptions of urban living improve, fewer "empty nesters" in dense urban areas feel the need to move and downsize.

Table 1
Historical and Projected Population, 1970–2040E

Municipality	1970	1980	1990	2000	2010	2040E
Boston	641,071	562,994	574,283	589,141	617,594	743,967
Cambridge	100,361	95,322	95,802	101,355	105,162	123,808
Somerville	88,779	77,372	76,210	77,478	75,754	101,971
Brookline	58,689	55,062	54,718	57,107	58,732	72,613
Medford	64,397	58,076	57,407	55,765	56,173	64,380
Revere	43,159	42,423	42,786	47,283	51,755	73,696
Arlington	53,523	48,219	44,630	42,389	42,844	45,159
Everett	42,485	37,195	35,701	38,037	41,667	60,434
Chelsea	30,625	25,431	28,710	35,080	35,177	42,054
Study Area	1,123,089	1,002,094	1,010,247	1,043,635	1,084,858	1,328,082
Rest of MPO	1,890,626	1,882,618	1,912,687	2,022,759	2,076,854	2,272,301
Entire MPO	3,013,715	2,884,712	2,922,934	3,066,394	3,161,712	3,600,383

E = Estimate.

Source(s): US Census (historical data), and Boston Region MPO Long-Range Transportation Plan (projections, 2015).

Population in the 92 non-study area municipalities declined only a little between 1970 and 1980 and by 2010 had increased 10 percent compared to 1970's population. Relative to the rapidly growing metropolitan areas in the Southwest during the same period, this would be modest growth, but it was enough to reinforce ongoing concerns about suburban sprawl. The theory and practice of realizing successful concentrated development has been an important aspect of the Boston region's land use and transportation-planning efforts.

The year 2040 projections in Table 1 show a 22 percent population increase in the study area, compared with only a nine percent increase in the outer 92 municipalities. These forecasts depend partly on how many potential developments studied by local and regional planning officials actually would be realized, and whether they would be residential or commercial.

Employment

Table 2 contains historical employment data collected by municipality as part of the federal ES-202 program. Except for the 2010 recession year, employment generally has increased in all locations.

Table 2
Historical and Projected Employment, 1970–2040E

Municipality	1970	1980	1990	2000	2010	2040E
Boston	450,628	505,360	537,664	583,922	552,369	646,947
Cambridge	80,016	92,044	103,278	115,612	105,861	123,396
Somerville	16,633	17,949	20,136	23,206	21,258	32,839
Brookline	17,184	17,112	18,123	16,421	15,368	20,740
Medford	14,144	15,176	19,513	20,262	17,190	19,255
Revere	6,359	7,644	8,176	8,777	9,163	8,878
Arlington	6,716	7,668	9,153	8,605	8,009	8,790
Everett	11,346	13,163	12,086	10,398	11,952	17,043
Chelsea	10,385	9,667	9,670	13,116	13,544	17,138
Study Area	613,411	685,783	737,799	800,319	754,714	895,026
Rest of MPO	616,974	814,120	961,259	1,075,520	1,063,560	1,135,938
Entire MPO	1,230,385	1,499,903	1,699,058	1,875,839	1,818,274	2,030,964

E = Estimate.

Source(s): Boston Region MPO Long-Range Transportation Plan (projections, 2015), and Bureau of Labor Statistics Form ES-202 (historical data).

National employment trends reinforced this pattern, as the numerous baby boomers born between 1946 and 1964 entered the workforce in the 1970s. In the 1990s, a combination of demographic, policy, and economic conditions brought large numbers of new workers into the job market. Programs such as Job Access and Reverse Commute (JARC) complemented this wave of workforce entrants.

The study area, particularly Boston and Cambridge, contains important regional job centers, though its share of regional employment appears to have permanently declined. In 1970, the study area contained 37 percent of the MPO region's residents, but 50 percent of the jobs. By 2010, only 34 percent of the region's residents lived in the study area, but the percentage of jobs had dropped to 42 percent. The 2040 projections show the study area returning to 37 percent of the population, with employment rising only to 44 percent.

Thus, the study area's projected shares of population and employment reflect well-recognized trends: Subject to the cost of housing and its availability, cities are becoming popular places to live. Downtown areas also are attracting new classes of white-collar workers, sometimes referred to as "knowledge" or "creative" workers in research, design, software, and marketing, adding upward pressure on commercial real estate prices.

Density

This study examines and estimates the transportation impacts of adding major new developments in locations that already may experience serious congestion. Clearly, urban density is a factor in creating new or mitigating already-congested conditions in Boston regional transportation systems.

MPO staff used the values presented in Tables 1 and 2 to estimate 20-year density trends. Dividing selected fields in these two tables by the size of their respective land areas results in the population and employment densities shown in Table 3. The entire MPO area covers 1404 square miles, of which the study-area municipalities make up only 91 square miles. The largest city, Boston, is 49 square miles and Chelsea, the smallest, is only 2.2 square miles. Study-area and non-study municipal land areas are listed in Appendix A.

Table 3
Population and Employment per Square Mile, 1970–2040E

Municipality	Population				Employment			
	1970	1990	2010	2040E	1970	1990	2010	2040E
Boston	13,164	11,792	12,682	15,277	9,253	11,040	11,342	13,284
Cambridge	15,440	14,739	16,179	19,047	12,310	15,889	16,286	18,984
Somerville	21,653	18,588	18,477	24,871	4,057	4,911	5,185	8,010
Brookline	8,631	8,047	8,637	10,678	2,527	2,665	2,260	3,050
Medford	8,050	7,176	7,022	8,048	1,768	2,439	2,149	2,407
Revere	7,441	7,377	8,923	12,706	1,096	1,410	1,580	1,531
Arlington	10,293	8,583	8,239	8,684	1,292	1,760	1,540	1,690
Everett	12,496	10,500	12,255	17,775	3,337	3,555	3,515	5,013
Chelsea	13,920	13,050	15,990	19,115	4,720	4,395	6,156	7,790
Study Area	12,382	11,138	11,961	14,643	6,763	8,134	8,321	9,868
Rest of MPO	1,439	1,456	1,581	1,730	470	732	810	865
Entire MPO	2,146	2,081	2,251	2,564	876	1,210	1,295	1,446

E = Estimate.

Source: Central Transportation Planning Staff.

In Table 3, it is clear that the densities do not vary as widely as do the cardinal values in Tables 1 and 2. For population, the densest study-area municipality is Somerville, with 18,477 residents per square mile. For employment, Cambridge is densest, with 16,286 workers per square mile. Somerville and Cambridge still are projected to be the densest municipalities in 2040, by an even a wider margin than they are today.

Table 3 indicates that the study-area population density is always a little less than ten times the density of the outer 92 municipalities. For employment, the study-area density is always more than ten times that of the outer 92 municipalities, though in 2010 it was barely so.

Density Trends

One way of appreciating the problem of adding development in areas that already are largely developed is to look at changes in density over time. MPO staff used the data in Table 3 to arrive at the values in Table 4, which shows how population and employment density have changed since 1970, and how they are projected to change in the future.

The meaning of density trends may be illustrated by a specific example. In the case of Somerville's population, each year between 1970 and 1990 every square mile in the city lost an average of 153 residents. During a 20-year period, this represents a loss of 3,060 residents per square mile. There are 4.108 square miles in Somerville, resulting in a total decline of 12,569 residents, from 88,779 in 1970 to 76,210 in 1990, as shown in Table 1.

Somerville's population declined slightly between 1990 and 2010, but between 2010 and 2040, staff expect the city to add an average of 213 residents per square mile each year. This translates to 6,390 more residents per square mile than in 2010; and accounts for the density increase shown in Table 2, from 18,477 in 2010 to 24,871 residents per square mile in 2040. As shown in Table 1, the citywide population is projected to reach 101,971 in 2040.

Table 4 shows that, expressed as density trends, historic and projected changes in MPO-region population and employment are not particularly dramatic and are reasonably aligned with recent trends. Even with the economic downturn in 2008, the region still managed to add four jobs per square mile per year between 1990 and 2010. From this low rate, a slight increase to five additional jobs per square mile per year is projected between 2010 and 2040.

Table 4
Density Trends—Change in Population and
Employment per Square Mile per Year, 1970–2040E

Municipality	Population			Employment		
	1970–1990	1990–2010	2010–2040E	1970–1990	1990–2010	2010–2040E
Boston	-69	+44	+86	+89	+15	+65
Cambridge	-35	+72	+96	+179	+20	+90
Somerville	-153	-6	+213	+43	+14	+94
Brookline	-29	+30	+68	+7	-20	+26
Medford	-44	-8	+34	+34	-15	+9
Revere	-3	+77	+126	+16	+9	-2
Arlington	-86	-17	+15	+23	-11	+5
Everett	-100	+88	+184	+11	-2	+50
Chelsea	-44	+147	+104	-16	+88	+54
Study Area	-62	+41	+89	+69	+9	+52
Rest of MPO	+1	+6	+5	+13	+4	+2
Entire MPO	-3	+9	+10	+17	+4	+5

E = Estimate.

Source: Central Transportation Planning Staff.

However, the projected population and employment increases are not uniform across the MPO region. Dramatically more residents and workers are forecasted to squeeze into each square mile each year in the study area than in the 92 outer municipalities. The outer municipalities will continue to add population at a steady rate, but employment growth is predicted to drop from four to just two additional jobs per square mile per year between 2010 and 2040. This is the problem addressed in this study: the greatest increases in density will be in areas that already are dense.

2.4 Considering Large-Impact Development Projects

The Importance of Large-Scale Developments

Much of the projected growth described in the previous section will be realized through a large number of smaller projects as well as more intense usage of existing structures. This type of development will happen throughout the region, but its effect will be felt most intensely in the study area. Not only are the study-area municipalities already densely developed, they also are projected to add further substantial population and employment. Moreover, many of the new trips generated in the suburbs need to pass through parts of the study area.

Some of the region's largest development sections are in the study area, and a representative sample of these is the focus of this study. These locations can be individual projects or groups of projects. Their individual and collective scale makes them especially relevant for several reasons:

- They can completely transform large urban areas. The rubric “city building” sometimes is used to characterize large-scale positive urban design impacts.
- Developers can consider prospective users as a group. Co-location of housing, employment, and retail venues can reduce travel somewhat per resident or worker even if the total increase in travel is substantial.
- Nearby portions of the transportation system may be optimized to accommodate new development. Large-scale developments have the potential to enter into mitigation agreements that enable substantial and mutually advantageous improvements.
- Large-scale developments generate significant regional travel demand that planners can predict and analyze.

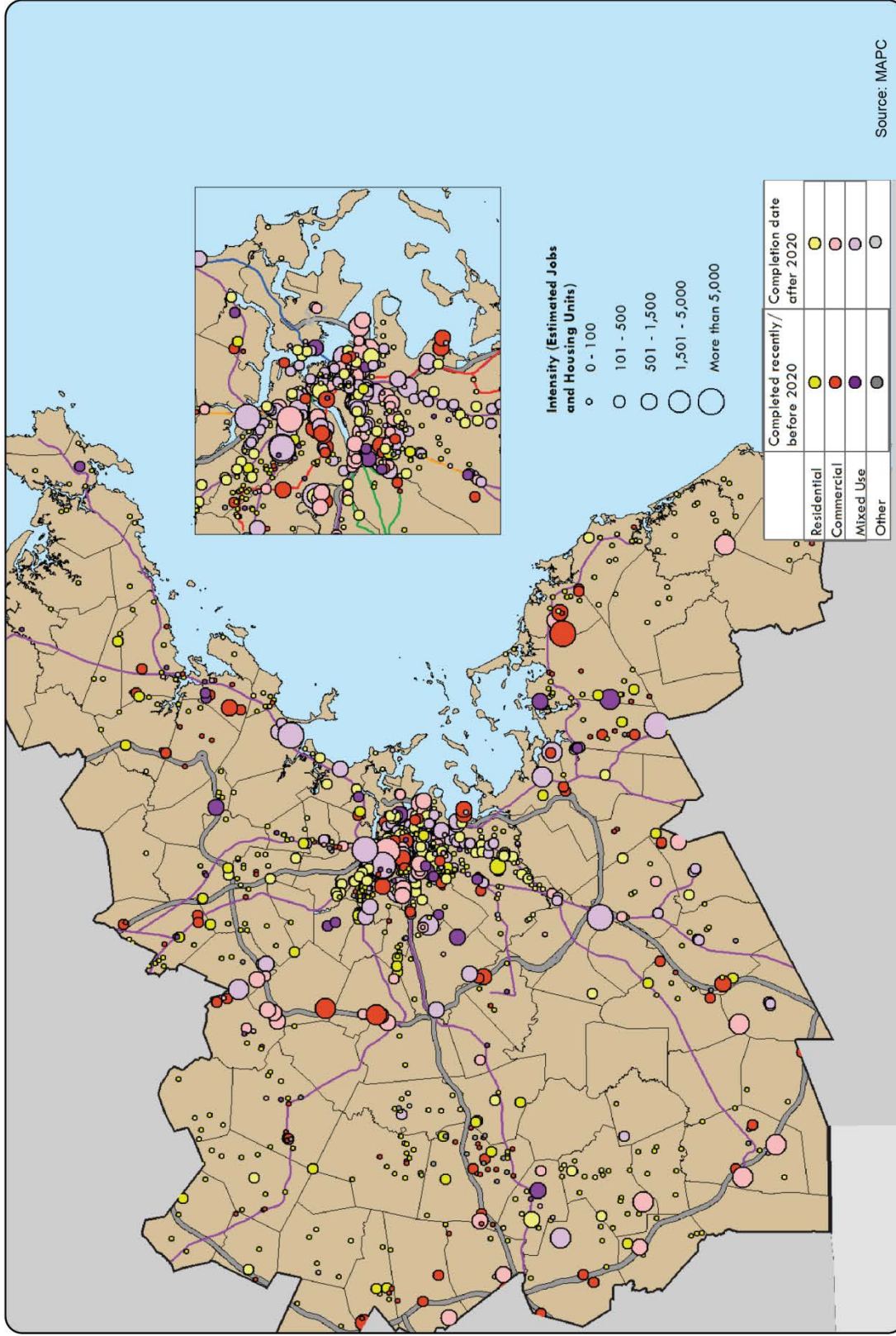
The demographic growth described in the previous section will present major challenges to the region’s transportation systems. While much of the growth will come from small- and medium-sized developments, it is useful to evaluate the large-impact projects as a group to estimate the nature and extent of their impacts on regional transportation.

All large-impact projects are required to mitigate their environmental impacts, including the burden of increased transportation demand, to some degree; yet, it is not clear if mitigation requirements are efficient, effective, or even sufficient. Projecting the combined impacts of these developments may be useful when reviewing mitigation programs in the study area.

Representative Sample of Large-Impact Developments

One of the inputs used in developing the 2040 demographic projections is a database of regional development projects maintained by the Metropolitan Area Planning Council (MAPC). This database contains approximately 3,000 projects that are planned, under construction, or recently completed. The database contains project descriptions, which allows for a preliminary estimate of the demographic and transportation impacts of each project. If all 672 projects listed for the study area were completed as described, these projects alone could add 180,000 new residents and more than a quarter-million new jobs. The entire database is shown graphically in Figure 2.

The 2040 demographic projections that were developed for the MPO’s Long-Range Transportation Plan (LRTP) also consider trends in broad-based demographic metrics such as household size and percentage of the population that is working or seeking work—that is, the labor-force participation rate. The development database and the LRTP trends both envision strong growth in the



BOSTON
REGION
MPO



FIGURE 2
Regional Development Database

Core
Capacity
Constraints

nine study-area municipalities. The development database is necessary, however, to identify and characterize the specific projects that are included in the sample of large-impact developments.

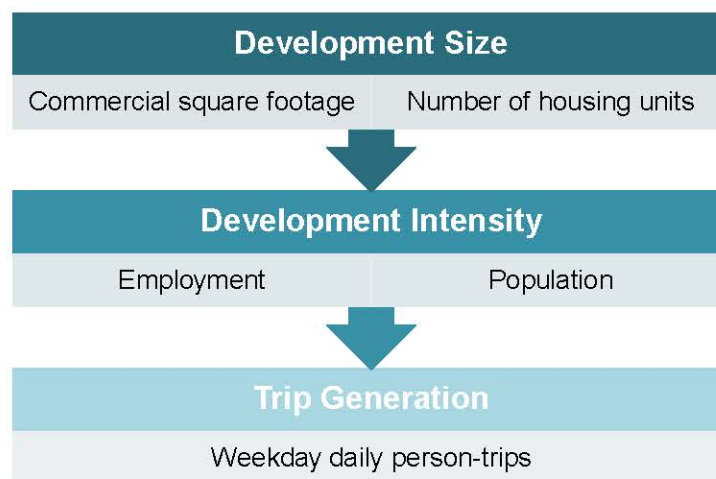
The regional travel demand model now used by MPO staff cannot model travel for an individual location. Instead, the 164-municipality model region (see Figure 1) has been divided into 2,727 transportation analysis zones (TAZs). Staff estimate the number of trips that begin or end in a TAZ based on the types of households and employment presently, or projected to be, located in the TAZ.

Estimating travel demand for individual developments is not necessary because staff analyze an entire TAZ. Indeed, most large developments are actually groups of developments with different owners, investment strategies, and permit and construction timetables. For this study, staff identified 20 TAZs within which the expected development projects would generate large numbers of trips.

Estimating the Number of Trips

Estimating the number of trips that a planned project would generate involves three steps (Figure 3). First, staff characterize projects in MAPC's regional development database according to their projected number of housing units and square feet of non-residential floor space. Second, the numbers of workers by industry sector are calculated using floor-space-per-worker values. Population estimates are based on local household sizes. Finally, weekday person-trips by purpose are generated from population and employment figures. In this analysis, staff used trip-generation formulas estimated with data from the 2011 Massachusetts Travel Survey.

Figure 3
Trip-Estimation Process



Source: Central Transportation Planning Staff.

Representative Sample of TAZs

Figure 4 cites the 20 TAZs selected for the representative sample, as well as the 72 specific large-impact projects planned for these TAZs. The TAZs selected are not necessarily those with the greatest projected increase in trips, but those that have not been studied recently. The regional impacts of developments in the South Boston Waterfront, Allston interchange, and Everett casino areas have been and continue to be studied exhaustively, and TAZs from these areas were not included in the sample. Projects within the 20 sample TAZs are important both individually and collectively, but if they were studied at all previously, it was primarily to understand their local impacts. For this study, the new projects in the sample TAZs are analyzed as a group and their regional impacts as a group are estimated.

Future travel-demand forecasts that include the 72 large-impact projects in the 20 sample TAZs are considered to be the Build scenario; which travel demand conditions reflect the LRTP demographic forecasts shown in the previous section. If the number of assumed 2040 trips were reduced by the trips that would be generated by the 72 large-impact projects, this reduced level of trips would be the No-Build scenario. In this study, the term “build” refers to adding travel demand through development rather than adding system capacity.

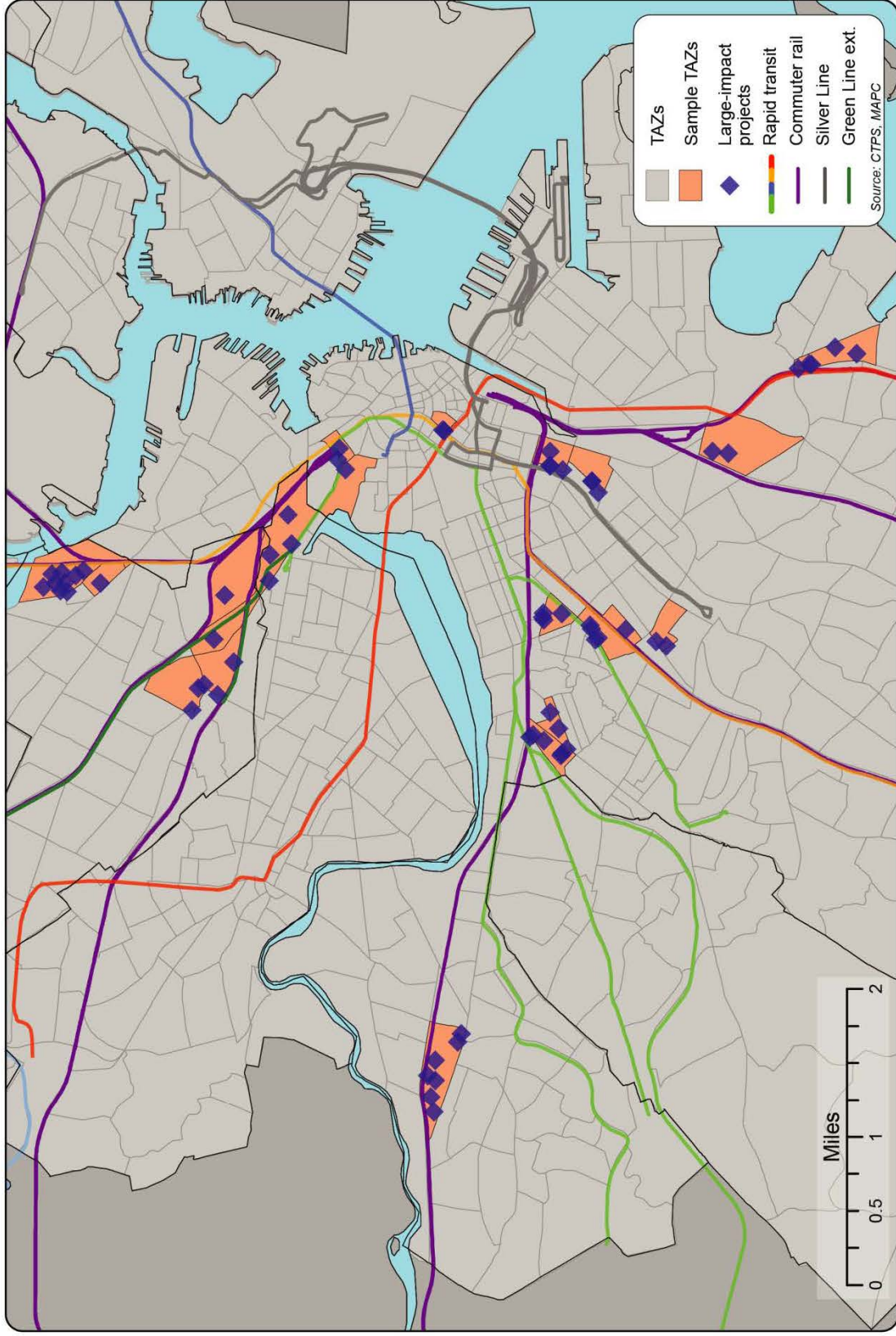
The locations of the 20 sample TAZs—all in Somerville, Cambridge, or Boston—are shown in Table 5, and are arranged roughly from north to south. Descriptions of large-impact projects, both within and outside the sample TAZs, are presented in Appendix A.

Table 5
Sample TAZ Locations, as of 2016

City	Project or Local Feature	City	Project or Local Feature
Somerville	Assembly Row	Boston	Downtown Crossing
Somerville	Assembly Square	Boston	Landmark Center
Somerville	Prospect Hill	Boston	Yawkey Way
Somerville	Union Square	Boston	Christian Science Center
Somerville	Brickbottom	Boston	Ink Block
Somerville	Inner Belt	Boston	Harrison/Albany
Cambridge	North Point	Boston	Northeastern University
Boston	West End	Boston	Tremont Crossing
Boston	Old Boston Garden site	Boston	South Bay
Boston	Brighton Landing	Boston	Morrissey Blvd./JFK

TAZ = Transportation analysis zone.

Source: Central Transportation Planning Staff.



BOSTON
REGION
MPO



FIGURE 4
Representative Sample of Traffic Analysis
Zones (TAZs) with Large-Impact Developments

Core
Capacity
Constraints

Chapter 3—Commuting and Travel Trends

3.1 Commuting by Study-Area Residents

Commuting Trends

The demographic trends since 1970 presented in the previous section have added a significant amount of travel demand to the study area and the region as a whole. The challenge of more residents has been compounded by a gradual increase in labor force participation and these trends have resulted in longer commute times and distances.

Table 6 presents a summary of commuting statistics for the study area. The first row of the table indicates the total study-area population for 1980 and 2010, taken from Table 1. The population increase during this 30-year period was 8.3 percent. One of the trends of this period was greater labor force participation, reflected here by an increase in the percent of residents employed. The number of employed residents rose by 20.8 percent, representing increases in both population and labor force participation.

Table 6
Study Area Commuting Trends, 1980–2010

	1980	2010	30-Year Increase	Percent Increase
Study Area population	1,002,100	1,084,900	82,800	8.3%
Employed residents	459,800	556,300	96,500	20.8%
Percent of residents employed	45.9%	51.3%	5.4%	--
Average commute time (in minutes)	24:30	28:00	3:30	14.6%

These data had been compiled by the US Census as part of the decennial census and were summarized in its Journey-to-Work database. After year 2000, commuting data was collected as part of the American Community Survey (ACS) sample. These survey efforts by the Census are comparable and allow the calculation of the 30-year trend shown in this table.

Source: US Census Bureau.

The last row in Table 6 cites the average of commute times reported to the Census by study-area respondents. The average 2010 commuting time was more than three and a half minutes longer than it was in 1980. The addition of almost 21 percent more commuters definitely would add congestion and slow traffic. The average commute distance also increased during the 30-year period; and there was a small relative decrease in commuting by auto, which still is the fastest commuting mode.

Mode Choice Trends

The Census also asks about the usual commuting mode, and these results are summarized in Table 7 for 1980 and 2010. Four commuting options grew by a larger percentage than did growth in employed residents. Commuting via private vehicle grew by only 15 percent, and the use of “other modes,” such as taxi and employer van declined.

Table 7
Study Area Mode Choice Trends, 1980–2010

Commute Mode	1980	2010	30-Year Change	Percent Change
Commuting Options:				
Private vehicle	243,000	280,000	37,000	15%
Transit	135,400	165,200	29,700	22
Walk	59,000	72,400	13,400	23
Bicycle	9,000	12,700	3,700	41
Other modes	7,300	5,800	(1,500)	(21)
Work at home	6,100	20,200	14,100	234
Employed residents	459,800	556,300	96,500	21
Mode Shares:				
Private vehicle	52.9%	50.3%	(2.5)%	--
Transit	29.5	29.7	0.2	--
Walk	12.8	13.0	0.2	--
Bicycle	2.0	2.3	0.3	--
Other modes	1.6	1.0	(0.5)	--
Work at home	1.3	3.6	2.3	--
All Commuting Options	100.0%	100.0%	0.0%	--

Source: US Census Bureau.

Use of transit and walking as commuting modes grew by 22 and 23 percent, respectively, slightly faster than the growth of employed residents. Standout growth was posted by the bicycle and “work at home” commuting options, growing by 41 and 234 percent, respectively.

Looking at the increase in actual numbers, commuting during the 30-year period tells a somewhat different story. There were 96,500 more employed residents in the study area in 2010 than in 1980. New telecommunications technologies have made it possible for 14,100 of these added workers to work at home and avoid commuting on a typical workday. Yet despite these new technologies, the other 82,400 additional workers had to travel to their primary workplaces.

Commuting by private auto was the choice of 37,000 additional commuters. While this was an increase of only 15 percent, it still represents the largest increase in absolute numbers of any mode. Conversely, the strong 41 percent increase in commuters by bicycle resulted from only 3,700 added commuters using this mode.

This analysis points to the need to accommodate a significant increase in vehicular traffic and transit ridership during peak commuting times. The non-motorized modes continue to be increasingly popular, and technology has made working from home a viable option. However, a substantial amount of future employees will be using the study area's road and transit systems.

The lower half of Table 7 expresses the mode share trends as percentages, which did not change dramatically during the 30-year period. Work at home, which is an option rather than a mode, *per se*, is now a more popular option than commuting by bicycle. While it grew in absolute numbers, commuting via private vehicle is now the choice of barely over half of commuters.

Trends in Commute Distances

MPO staff used detailed data from two large-scale household surveys to calculate commuting distance trends; Table 8 cites increases in commuting distances for motorized travel modes. In order to construct reliable comparisons, staff calculated commuting distances for the entire 164-municipality model region (see Figure 1).

Table 8
Regional Commuting Trends
Average Miles between Residence and Primary Workplace, 1991–2011

Commute Mode	1991	2011	20–Year Increase	Percentage Increase
Auto	8.5	9.4	0.9	10.0%
Drive-access transit	13.3	15.6	2.3	17.3
Walk-access transit	4.9	5.8	0.9	18.4
All motorized modes	8.4	9.4	1.0	11.9

Source(s): 1991 Household Travel survey, and 2011 Massachusetts Travel Survey.

Over and above demographic growth, commuters' need to travel farther to reach their workplaces adds significantly to the burdens placed on the region's transportation systems. We expect that commutes would lengthen for a number of reasons. First, added housing or jobs in outer suburbs would make for possible long commutes, as workers seek their ideal job match. While the study area is projected to experience robust growth, we expect the outer suburbs also

to continue to grow. In addition, regional land values suggest that new, lower-cost housing more likely would be built in areas farther from the urban core.

Building housing near employment is seen as a development strategy that might reverse or slow the trend of gradually increasing commuting distances. While this is a reasonable expectation, it needs to be viewed in context. If a couple acquires a residence at the location of one person's workplace, the other partner still may need to commute by auto or transit. People change jobs or are relocated by their employer, and new job opportunities are constantly being created throughout the region. The problem is that it is simple to locate an individual near a job, but it is almost impossible to locate an entire household somewhere with short commuting distances for all household members.

The longest-distance commuting option shown in Table 8 is drive-access transit, which increased from an average distance of 13.3 miles in 1991 to 15.6 miles in 2001. Another development strategy that could reduce transportation impacts is transit-oriented development; and new and existing suburban housing developments are advertised routinely as being convenient to the expanding commuter rail system. Since 1991, commuter rail service has been introduced to distant commuting markets in Newburyport, Middleborough and Plymouth, and service to Worcester and Providence has been greatly increased. As in the previous example, one household member may have a convenient commute by transit to the urban core, but other household members might commute to any regional location.

Commuting Today

We may form a more complete picture of study-area commuting by using information from the 2011 Massachusetts Travel Survey to divide 2010 Census commuting data into distinct commuting patterns. Commuting trends are difficult to estimate reliably at this level of detail, and only the 2011 commuting data has been summarized in Table 9.

About one-fourth of the employed study area residents make what is referred as a "reverse commute," meaning that they reside in a defined urban core but commute to work in an outlying area. Most of these 142,500 commuters drive to work, as shown in the right-most column of Table 9.

Table 9
Study Area Commuting Patterns in 2011

Commute Mode	Radial Commutes	Within Study Area	Reverse Commutes
<i>Commuting Options:</i>			
Private vehicle	174,500	153,100	126,900
Transit	150,600	153,300	11,900
Other modes	15,800	87,200	3,700
Work at home	N/A	20,200	N/A
Total Commuters	340,900	413,800	142,500
<i>Mode Share Percentages:</i>			
Private vehicle	51.2%	37.0%	89.1%
Transit	44.2	37.0	8.4
Other modes	4.6	21.1	2.6
Work at home	N/A	4.9	N/A
All Commuting Options	100.0%	100.0%	100.0%

N/A = Not applicable or available.

Source(s): US Census Bureau, and 2011 Massachusetts Travel Survey.

The three-quarters of employed study-area residents who also work in the study area make up 55 percent of the study area's workforce, and their travel mode preferences are shown in the middle column of Table 9. Because these commutes both begin and end in the study area, the use of "other modes" is comparatively popular. These include walking, bicycling, and traveling by taxi, all of which are generally used for shorter trips than auto or transit. As seen in the lower part of Table 9, 21 percent of "other modes" are used for commutes entirely within the study area. At 37 percent, autos have their lowest share in this commuting market segment.

The remainder, 45 percent, of the study area workforce lives outside of the study area and makes a traditional "radial" commute—that is, with the workplace in the urban core and the residence in a suburb. At 42 percent, transit achieves its highest mode share in this market segment, but still is exceeded by driving, the choice of 51 percent of these commuters. Because of the longer commuting distances, the use of "other" modes is limited in this market segment.

In Table 9, the commuting is concentrated during the AM and PM peak periods, and represents in aggregate the capacity and congestion burden that the region's transportation systems must bear. The demographic and commuting trends discussed above clearly imply that these burdens will increase substantially in the future.

3.2 Travel Trends in the Transportation Subsystems

Mass Transit Trends

As shown in Table 7, 22 percent more study-area residents commuted by transit in 2010 than they did 30 years earlier in 1980. This figure agrees generally with the MBTA system ridership trends summarized in Table 10. During the 23-year period between 1990 and 2013, weekday use of all the MBTA's fixed-route services increased by 17 percent.

Table 10
MBTA Average Weekday Ridership Trends, 1990–2013

Mass Transit Subsystem	1990	2013	23-Year Increase	Percent Increase
Red Line	181,800	237,800	55,900	31%
Orange Line	117,300	150,100	32,800	28
Green Line	67,600	74,300	6,700	10
Blue Line	50,200	52,300	2,100	4
Northside commuter rail	14,400	25,000	10,600	74
Southside commuter rail	23,200	41,900	18,700	81
Bus	377,900	388,600	10,600	3
Total System Entries	832,400	970,000	137,600	17%

Source(s): MBTA Ridership and Service Statistics, Fourteenth Edition, 2014, and National Transit Database.

While the combined 17 percent ridership growth reflects overall commuting trends, the individual subsystems have experienced a wide range of growth. Because many transit trips require one or more transfers, too much should not be concluded from these growth differences. However, employment growth in places like Kendall Square and the Longwood Medical Area has contributed to strong Red and Green Line usage. In addition, ridership growth on the commuter rail is partly a result of system expansion and increased service on key lines. Growth in bus use appears low partly because in the 1990s buses substituted for Green Line service on the heavily used E Branch during its reconstruction.

The MBTA has been able to accommodate this growth to some extent by adding capacity in parts of its operations. The implications for system congestion because of added capacity can vary, and depend on the nature of the capacity added. Often, a highly visible capacity expansion would be to introduce a new fixed-route service in a previously underserved area. New services since 1990 include the three Old Colony commuter rail lines and the extension of commuter rail service to Newburyport. The Silver Line tunnel from a Red Line connection at South Station into the Seaport District also represents a new service to an underserved area. (Silver Line ridership is reflected in Table 10 in the bus and Red Line statistics.) These expanded services have been successful in attracting

new commuters to transit during peak periods. However, most of the new commuters must travel through the urban core to complete their trips, thus increasing congestion on already heavily congested transit lines.

Increasing the maximum number of passengers that the transit system can carry at peak periods is a critical type of capacity expansion. While these types of expansions often lack the public flair of a ribbon cutting, they help determine the comfort, convenience, and ultimate success of transit services. Purchasing double-decked commuter rail coaches and lengthening the Blue Line platforms to accommodate six-car trains were important and highly visible peak-period capacity increases. Older Orange and Red Line station platforms were lengthened prior to 1990 to accommodate six-car trains. For a time, six-car trains were operated during peak periods and four-car trains at other hours of the day, but by the early 1990s, six car trains were the norm. Transit ridership outside of the peak periods has increased steadily over the years; and the Red, Orange, and Blue Lines now operate with six car trains at all hours.

Several institutional issues had restricted the amount of commuter service that could be offered on the Worcester and Providence commuter rail lines. Before these issues were resolved, service to these major New England cities was mostly concentrated during peak periods. New institutional arrangements have allowed significantly expanded service on these lines, much of which, however, has been added outside of peak periods.

Finally, the extension of many Silver Line buses to Logan Airport has been very successful and has accommodated a significant amount of Logan's recent passenger growth. Travel to Logan Airport by both the Silver Line and the Blue Line is distributed throughout the day.

Roadway Trends

Limited-access express highways are critical corridors that make vehicular travel practicable between and across the study area and its outer suburbs and Massachusetts as a whole. Because of its importance, extensive and detailed historical data for the express highway system in Massachusetts have been developed and published by MPO staff. These data were developed for average weekdays; a summary of statistics relevant to this study is presented in Table 11¹.

Table 11
Vehicle-Miles Traveled on Limited-Access Highways:
Thousands of Vehicle-Miles on an Average Weekday, 1970–2010

	1970	1980	1990	2000	2010	Average Annual Increase
Study Area	2,800	3,800	4,600	5,200	5,700	73
Outer suburbs	14,700	21,400	33,600	42,100	44,700	750
Rest of state	5,800	8,900	13,400	17,700	20,000	355
Statewide	23,300	34,100	51,600	65,000	70,400	1,178

Source: Central Transportation Planning Staff.

MPO staff can allocate traffic volumes to specific regions using the express highway historical database. In Table 11, the area cited as “outer suburbs” refers to 155 municipalities outside of the nine in the study area that altogether form the Boston Region MPO travel demand model region (see Figure 1), and includes most of the area generating commuter trips into the study area.

Using weekday traffic on express highways to articulate traffic growth trends has certain implications. First, traffic on express highways is only a portion of overall traffic. The working assumption of this analysis is that overall traffic growth is roughly proportional to growth on the express highways. All traffic on limited-access highways must begin and end travel some place on the surface roads, so traffic growth on the express highways generally is accompanied by growth on the surface roads.

Another important implication of using weekday traffic as a measure is the way congestion is accounted for. As shown in Table 11, daily vehicle-miles traveled have steadily increased in all geographical areas. This is despite the fact that numerous locations on the express highway system, many of which are in the study area, reach their maximum capacity during the AM and PM peak periods.

¹ Traffic Volumes on Major Highways in Massachusetts, May 2007.

Increased daily traffic volumes impact already-congested roads in several ways. At the congested locations, the duration of peak congested conditions lengthens, as do the queues of traffic waiting to pass through the various bottlenecks. In addition, as queues lengthen at locations that have reached their maximum capacity, drivers seek alternate routes to bypass the bottlenecks. These alternate routes may be on a different express highway or on a parallel surface road. Over time, these alternate routes in turn can become congested.

The underlying data presented in Table 11 are not of a nature that could inform the design of specific highway system elements. Their purpose is to illustrate the fact that traffic and associated congestion have been steadily increasing, though at a more moderate pace than in previous decades.

Chapter 4—Roadway Capacity Issues

4.1 Roadway Capacity and Congestion

The ability of study-area roadways to absorb additional traffic generated by anticipated future development is a major concern of this study. The capacity of the roadway system has been evaluated by estimating the linear extent of congested traffic conditions on major study area roadways during the AM and PM three-hour peak periods in the 2012 Base Year and the 2040 future year in two distinct growth scenarios.

Staff used the Boston Region MPO travel demand model to estimate the extent and severity of traffic congestion for both 2012 and projected 2040 traffic conditions. The model includes a representation of all of the region's express highways and arterial roadways and many local streets. Each segment of the roadway system represented in the model is characterized by a capacity based on its physical design, expressed as a maximum number of vehicles per hour. In Appendix B, we discuss the preparation and use of the travel demand model.

The model estimates the amount of traffic on every segment of the roadway system for each modeled scenario by time period. The estimated volume of traffic is compared with the capacity of each roadway segment; this volume-to-capacity ratio is the measure used to identify the presence and severity of traffic congestion. A volume-to-capacity ratio of less than 0.85 is sufficiently below capacity to allow acceptable vehicle speeds, whereas a value greater than 0.85 is, for the purpose of this study, approaching capacity and is considered congested.

As traffic on a roadway segment increases to greater than 0.85 of capacity, traffic slows, with the negative impact of each added vehicle increasing its travel time. As traffic slows to a crawl, fuel efficiency declines and emissions per mile of pollutants and greenhouse gases increase. Queues usually form behind a congested section, with vehicles creeping up to a bottleneck on a road section that normally would have adequate capacity.

4.2 Base-Year and Projected Roadway Congestion

Base-Year Congestion

There are about 502 miles of limited-access express highways and arterial streets in the nine-municipality study area. In the 2012 Base Year, an estimated 123 miles of these roads carried more than 0.85 of their capacity during the AM peak period, meaning that 24.5 percent of the study area's major roadways were congested during this period (see Table 12). Base- and future-year congested roadways are listed and shown graphically in Appendix C.

Table 12
Major Roadway Congested Miles, 2012–2040E

Scenario	AM Peak Period		PM Peak Period	
	Miles	Percent of Miles	Miles	Percent of Miles
2012 Base Year	123	24.5%	197	39.2%
2040E No-Build	157	31.3	242	48.1
2040E Build	169	33.7	255	50.8

E = Estimate.

Source: Central Transportation Planning Staff.

In 2012, during the PM peak period, 197 miles, or 39.2 percent of study-area major roadways were congested, significantly greater than the amount of congestion during the AM peak period. This is because most of the traffic during the AM peak is part of a commute to work, whereas during the PM peak, commuting home is supplemented by a substantial amount of non-commuting traffic.

2040 No-Build Scenario Congestion

The 2040 No-build scenario reflects all of the regional demographic and travel growth projected for the Boston Region MPO's Long-Range Transportation Plan, except for the 72 key large-impact developments that were discussed previously. Even without these large-impact developments, the model results in Table 12 show that there will be 34 more miles of congestion on study-area major roadways during the AM peak period in 2040—157 congested miles, or 31.3 percent of the total miles.

The growth impact is even greater during the PM peak period, with an additional 45 miles of major roadway exceeding 0.85 of capacity in 2040. With a projected 242 congested miles, almost half of the total study-area major roadway miles would be congested during the PM peak.

2040 Build Scenario Congestion

The 2040 Build scenario includes all the regional demographic and travel growth projected for the Boston Region MPO's Long-Range Transportation Plan, including travel generated by the 72 key large-impact developments. With these large-impact developments included, the analysis shows an additional 12 miles of congested major roadway during the AM peak period, 169 miles compared with the 157 congested miles in the No-build scenario.

Including the large-impact projects adds an additional 13 miles of congestion during the PM peak in the Build scenario, comparable to the 12 miles of congestion added by these projects during the AM peak period. Taken

altogether, more than of half the major roadways would be congested during the PM peak in the Build scenario.

4.3 Congestion Associated with the Key Large-Impact Projects

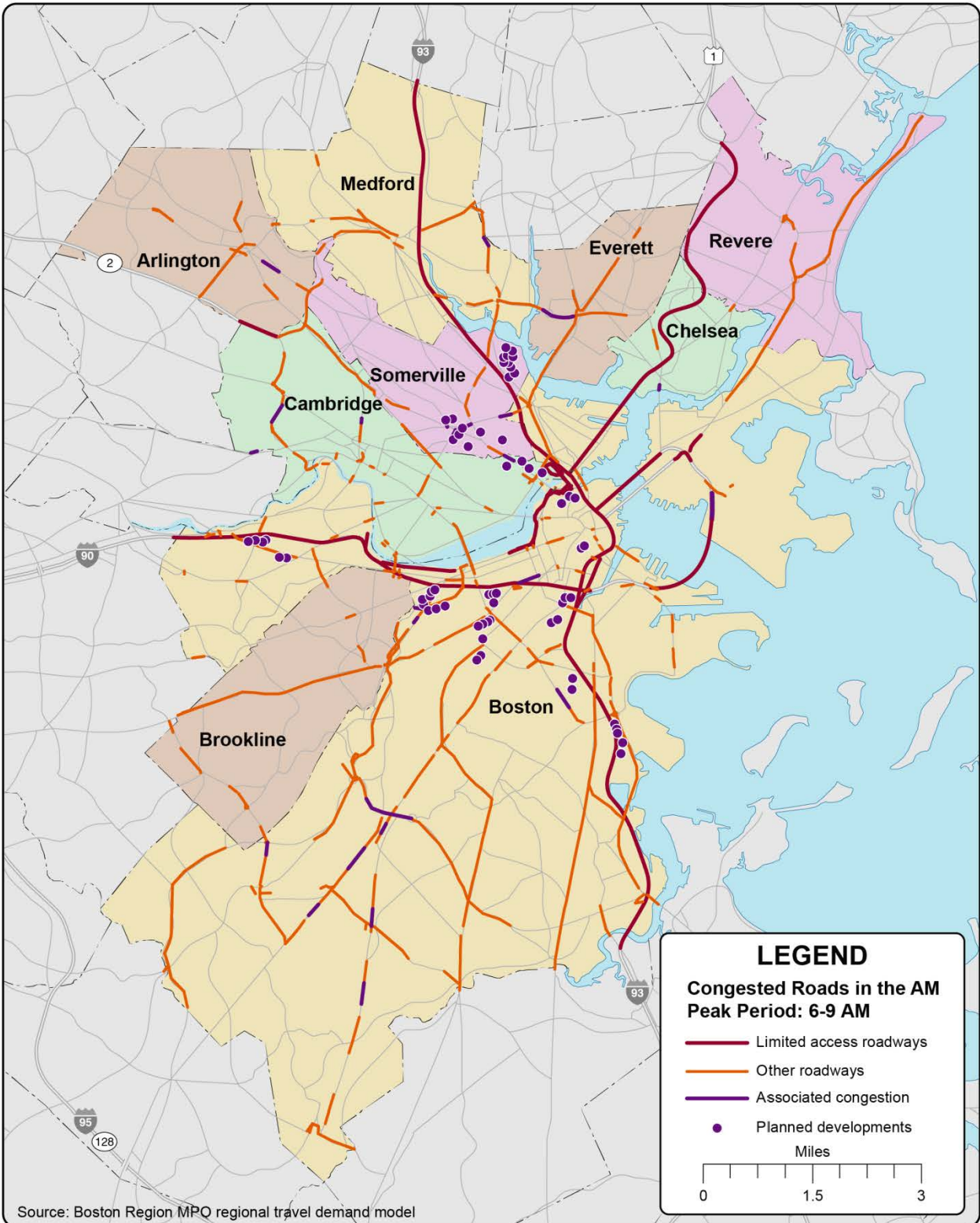
The nine study-area municipalities and major roadways are shown graphically in Figures 5 and 6. The 157 roadway miles congested during the AM peak period in the 2040 No-build scenario are highlighted in orange and red in Figure 5. Figure 6 highlights in two shades of blue the 242 congested miles during the PM peak period in the No-build scenario.

The locations of the 72 key large-impact projects also appear in both figures, in purple. The same shade of purple is also used to highlight in each graphic the major roadway segments where traffic volumes edge above the 0.85 of capacity mark because of adding the traffic from the Build-scenario projects. This added congestion is referred to as “associated congestion” because it exists in association with completing the Build-scenario projects.

Most of the associated congestion appears on radial arterials feeding traffic into the urban core and the sample large-impact projects. The purple line segments in Figure 5 total around 12 miles for the AM peak period and in Figure 6 they amount to around 13 miles for the PM peak period. While most of these segments are pointing into the urban core, much of the associated congestion is on segments at some distance from the large-impact projects. This illustrates the fact that, because of many vehicle trips are long, the traffic impacts of a development can be widespread.

The traffic impacts across the study area result from two factors. First, incremental traffic generated by large-impact projects may travel to or from relatively distant locations, pushing some borderline roadway segments along the travel route to greater than the 0.85 capacity level. Second, much of the newly generated traffic must use already-congested roads, some near the new projects. As the severity of existing congestion increases, traffic unrelated to the new development seeks less-congested routes farther from the new development, further spreading out the traffic impacts.

Also not apparent in these figures are non-congested roadways that are nearing the 0.85 capacity level. While traffic conditions at these locations may be satisfactory in the 2040-Build scenario, the ability to accommodate additional traffic is reduced. (This traffic growth could be either regional in nature or associated with projects envisioned for that particular area.)

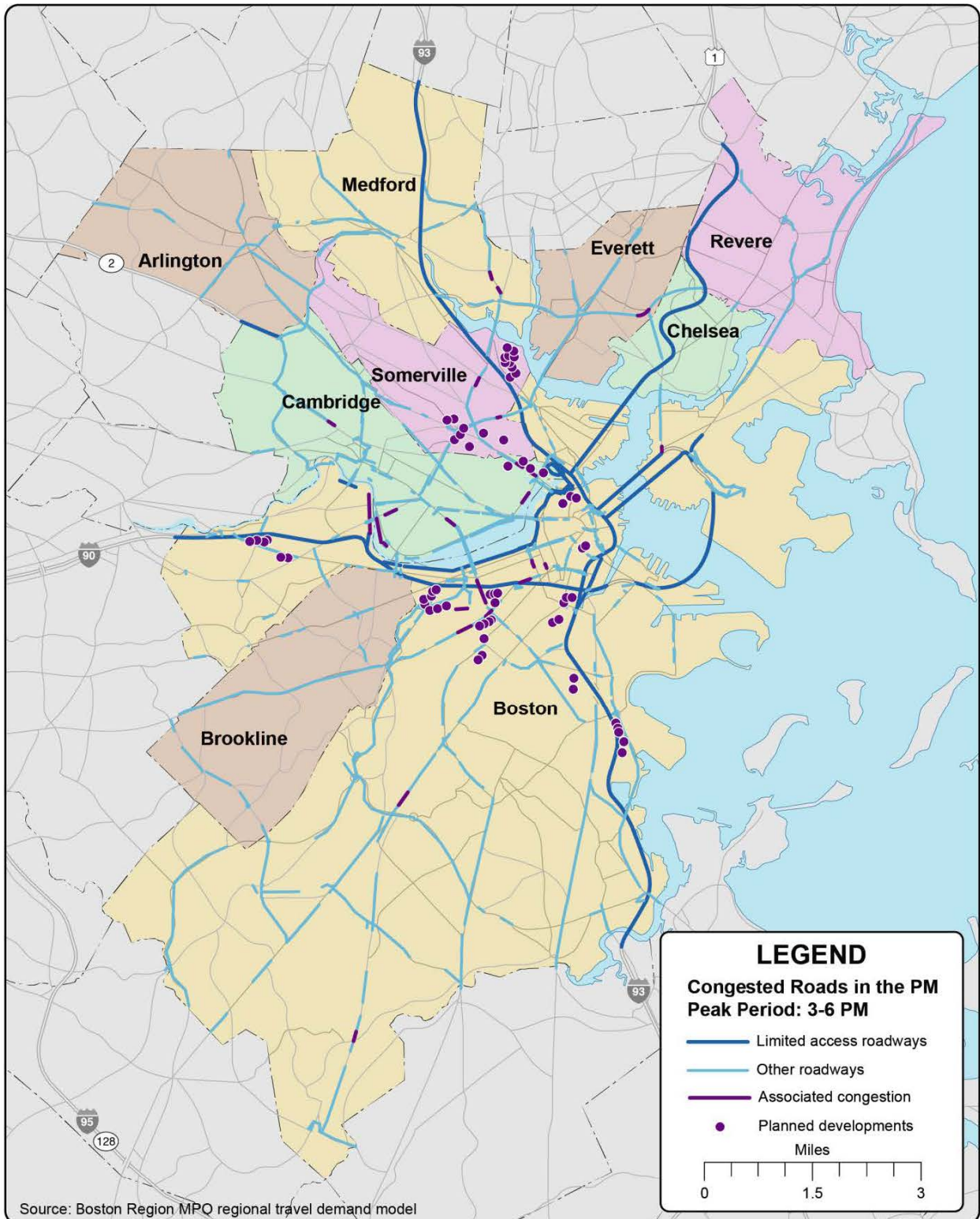


**BOSTON
REGION
MPO**



FIGURE 5
**Location of Build-Scenario Developments and
Associated New AM Congested Roadway Segments**

*Core
Capacity
Constraints*



**BOSTON
REGION
MPO**



FIGURE 6
**Location of Build-Scenario Developments and
Associated New PM Congested Roadway Segments**

*Core
Capacity
Constraints*

In conclusion, large-impact projects spawn traffic impacts throughout the region. When they are near a development site, the impacts can be more clearly attributed to a particular project. Farther from the development site, the added traffic is dispersed and is indistinguishable from the collective impact of smaller projects.

Chapter 5—Transit Capacity Issues

5.1 Projected Rapid Transit Ridership

The analysis of transit capacity begins with the region's complex and heavily used rail rapid transit system: the Red, Orange, Green, and Blue lines. The average weekday ridership numbers for the four MBTA rail rapid transit lines shown in Table 10 are also presented in Table 13. These numbers represent entrances to the system at stations with fare gates and show an increase of 97,600 riders between 1990 and 2013, for an average increase of about 4,200 weekday riders each year.

Forecasts for the four rail rapid transit lines are shown in Table 13. The 2040 ridership estimates are derived from the demographics and development forecasts presented in section 2 of this study, and the ridership forecasting methodology is described in Appendix B. The 2040 No-Build ridership estimates assume that all projected 2040 growth takes place except for the 72 large-impact projects in the 20 sample TAZs. The 2040 Build ridership estimates assume that these 72 projects are completed as well. These developments are listed in Table 5 and their locations are shown in Figure 4.

Table 13
Historical and Projected Weekday Rapid Transit Ridership

Rapid Transit Line	1990	2013	2040 No-Build	2040 Build
Red Line	181,800	237,800	337,000	359,000
Orange Line	117,300	150,100	184,000	228,000
Green Line	67,600	74,300	77,000	105,000
Blue Line	50,200	52,300	63,000	63,000
Total boardings	416,900	514,500	661,000	755,000

Source(s): Central Transportation Planning Staff, and MBTA Ridership and Service Statistics, Fourteenth Edition, 2014

In the No-Build scenario, weekday rapid transit station entrances are projected to increase by 126,500 during the 27 years between 2013 and 2040, to total 661,000 outside entrances. This would represent an increase of about 5,400 weekday riders each year, substantially greater than the 4,200 additional riders added each year before 2013. If all the projects in the Build scenario are completed, weekday station entrances are projected to reach 755,000 for these four lines, implying an annual increase of 8,900 weekday riders.

Increased ridership will impact all time periods, lines, and directions. However, crowding likely would be a problem during the AM and PM peak periods. In this

section, we discuss the relationship of crowding to overall system operations, and identify the time, locations, and severity of peak period crowding.

5.2 Measuring Capacity and Crowding on Rapid Transit Lines

The capacity of a transit line is calculated as the number of trains operated during a time period times the number of vehicles per train times a benchmark number of passengers per vehicle. In the short term, all three of these factors are fixed operational characteristics of a transit line.

The maximum number of passengers a rapid transit vehicle can carry depends only partly on fixed characteristics such as vehicle size, number of seats and their arrangement within the vehicle. In addition to accommodating a passenger in each seat, it is assumed that during peak periods there also will be a substantial number of standing passengers. When the number of standees reaches a maximum acceptable level, the vehicle may be considered to be operating at capacity even though there still might be room for “one more passenger.”

Transit equipment manufacturers provide estimates of a maximum theoretical capacity of their vehicles, which are based on design factors such as strength of the undercarriage and power of the electric motors; but these are not of value in service planning.

For the purposes of this analysis, we have defined three distinct crowding levels:

- **Overburdened:** Crowding is apparent
 - At least as many standees as seats
 - More than 88 percent of acceptably full on average
- **Overcrowded:** More than acceptably full
 - Less than 3.76 square feet per standee
- **Unacceptable:** Exceeds maximum acceptable load
 - Less than 3.11 square feet per standee
 - More than 12 percent above acceptably full on average

The concept of “acceptably full” is a characteristic of all three crowding levels. The availability of 3.76 square feet for each standing passenger is used as the cutoff point in determining when a vehicle is acceptably full. Staff selected this value based on published industry standards that are summarized in Table 14.

Table 14
Impact of Available Passenger Floor Space on Rapid Transit Service

Square Feet per Standee	Passenger Perspective	MBTA Operations Perspective
10.8 and above	<ul style="list-style-type: none"> • Passengers are able to spread out • Many/all passengers are able to sit 	<ul style="list-style-type: none"> • Unproductive
5.4 to 10.8	<ul style="list-style-type: none"> • Comfortable standing load that retains space between passengers 	<ul style="list-style-type: none"> • Easy circulation within vehicle
4.3 to 5.3	<ul style="list-style-type: none"> • Standing load without body contact • Standees have similar amount of personal space as seated passengers 	<ul style="list-style-type: none"> • Reasonably easy circulation within vehicle
3.2 to 4.2	<ul style="list-style-type: none"> • Occasional body contact • Standees have less space than seated passengers 	<ul style="list-style-type: none"> • Balance between passenger comfort and capacity • Potential for boarding and alighting delays and increased dwell time
2.2 to 3.1	<ul style="list-style-type: none"> • Approaching uncomfortable conditions • Frequent body contact and inconvenience with packages and briefcases 	<ul style="list-style-type: none"> • Maximum schedule load • Increased dwell time • Passengers waiting to board may try to shift to a door in a less-crowded section
Less than 2.2	<ul style="list-style-type: none"> • Crush-load conditions 	<ul style="list-style-type: none"> • Moving to and from doorways extremely difficult • Increased dwell times • Passengers waiting may choose to wait for next vehicle, increasing platform crowding

Source: Adapted from Transit Capacity and Quality of Service Manual, 3rd Edition.²

As described in Table 14, the quality of a transit user's experience is diminished as the number of riders in a vehicle increases. Conversely, the transit system operator benefits from carrying a greater number of passengers, but only up to a point. With too much crowding, unloading and loading passengers at stations can be time consuming and make it difficult to adhere to schedule. The selection of 3.76 square feet per standee as the definition of an acceptably full vehicle represents a balance between passenger comfort and operational efficiency.

²Transportation Research Board, *Transit Capacity and Quality of Service Manual*, 2013, http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_165ch-05.pdf.

The MBTA operates several distinct vehicle fleets on its four rail rapid transit lines. Currently, most of these vehicles are configured with so-called “perimeter seating”—that is, most seating installed along the sides of cars to allow for a large number of standees. Dividing the available standing space by 3.76 square feet per passenger gives the maximum number of standees in an acceptably full vehicle. Adding the number of seats to the number of standees gives the total passenger load of a rapid transit vehicle.

Table 15 summarizes transit vehicle capacities for the MBTA fleets for the different congestion levels used in this analysis. For the Red and Green Lines, where the MBTA uses more than one type of vehicle, the figures in Table 15 represent average values for the line.

Table 15
Passenger Capacities and Crowding on Rapid Transit Vehicles

Transit Line	Seating Capacity	Apparent Crowding	Acceptably Full	Maximum Acceptable	Physical Limit
Red	57	114	142	160	202
Orange	58	116	124	138	171
Green	45	90	100	112	139
Blue	35	70	76	85	105

Source: Adapted from MBTA Ridership and Service Statistics, Fourteenth Edition, 2014.

The first column in Table 15 shows the number of seats available for a typical car on each line. The Orange Line cars have the greatest number of seats despite being smaller than the Red Line cars. This is because all Orange Line cars have only three doors on each side and have not had seats removed to create specific locations to secure wheelchairs. In contrast, many of the Red Line cars have a fourth door on each side and locations for wheelchairs, both of which reduce space available for perimeter seating.

The second column in Table 15 shows the number of seats multiplied by two, and indicates the “overburdened” crowding level, at which crowding becomes apparent to riders but still is considered an acceptable, even efficient level of vehicle utilization. Vehicles with this many riders are, on average, within 12 percent of the acceptably full benchmark.

When the number of riders exceeds the acceptably full benchmark, the vehicle is considered to be overcrowded. When there are fewer than 3.11 square feet per standee, the level of crowding is considered unacceptable; the maximum acceptable number of passengers for each type of MBTA transit vehicle is shown in the fourth column of Table 15. The maximum acceptable loads, on average,

are about 12 percent higher than the acceptably full benchmark and approximate the maximum load specified by the MBTA Service Delivery Policy.

The right-most column in Table 15 approximates a practical physical limit of a vehicle's passenger load and assumes only 2.20 square feet per standee. At greater than this level, a point is reached where the motive power or vehicle suspension is inadequate for safe operation. Crowding approaching so-called "crush loads" can occur after sports events or during peak periods if a train needs to be taken out of service.

Using the acceptably full passenger load benchmark, it is possible to calculate a total capacity for each of the four rail rapid transit lines, as summarized in Table 16. The first column in Table 16 shows the average number of weekday trains that operated on each transit line in May 2011. These numbers were obtained from direct observation rather than calculated from schedules. For the Blue and Red Lines, the number of observed trains exceeded 97 percent of the scheduled trains. The number of Orange Line trains observed was less than 93 percent of scheduled trains. Comparable information for the Green Line was not developed.

Table 16
Total Daily Rapid Transit Capacity

Transit Line	Number of Daily Trains in Each Direction	Cars per Train	Acceptably Full Car Capacity	Total Daily Capacity
Red	205	6	142	175,000
Orange	149	6	124	111,000
Green	562	2	100	112,000
Blue	171	6	76	78,000

Source: Central Transportation Planning Staff.

The second column shows the number of cars per train, with six cars being standard for the Red, Orange, and Blue Lines. On weekdays, almost all the Green Line trains have two cars. The third column is the acceptably full car capacity benchmark from Table 14. Multiplying these three columns gives the total number of passengers that each rapid transit line could move in each direction over the course of a weekday if all vehicles were acceptably full, shown in the right-most column.

The total capacities in Table 16 represent the daily capacity as currently operated. The MBTA schedules as much service as practicable during the AM and PM peak periods, and then reduces service somewhat during the off-peak periods. Capacity during the peak periods will be constrained by either the

number of transit vehicles available or the design of the signaling and safety systems.

We may conclude from Table 16 that the Red Line provides significantly more raw capacity than the other lines. In theory, more off-peak service could be added on the other lines. However, if increased off-peak travel demand warranted increased service, then off-peak trains likely would be added to all four lines, maintaining the Red Line's capacity advantage.

Increasing the carrying capacity of a rapid transit line clearly has the potential to reduce crowding. These types of efforts have been ongoing for decades; and opportunities to increase capacity will be discussed in later in this report in analyses of the individual lines. For the purpose of this study, however, we assume the vehicle capacities and train configurations shown in Tables 15 and 16 in evaluating expected future crowding.

5.3 Rapid Transit Capacity as it is Actually Experienced

The raw physical capacity calculated in Table 16 is available for use between the service end points of each rapid transit line. In daily use, however, more passengers board trains at certain stations than others and only travel a portion of the route. At each intermediate station passengers both board and alight, and the number of daily boardings on a line does not relate directly to its raw capacity. This may be seen by comparing 2013 weekday ridership of the four lines in Table 13 with their total weekday capacities calculated in Table 16. Usually, however, higher-capacity transit lines can accommodate more boardings and longer trip distances before crowding becomes a problem.

The analyses in this study depict the availability of transit capacity as closely as possible to the way it actually is experienced by users. As mentioned above, capacity and service were based on train trips that actually operated rather than the level of service in published schedules.

Observed rapid transit operations also deviate from published schedules in that trains are often unable to arrive at regular time intervals. The dwell time required at station stops varies, often as a result of a large number of passengers transferring from a just-arrived connecting train. If a longer than anticipated station stop results in a slightly delayed departure, the result is greater numbers of riders accumulating on station platforms down the line, which in turn can lengthen dwell times at these stations.

Conversely, the train immediately behind a delayed train may have shorter dwell times as it gets closer to the slower train in front because fewer riders have had a

chance to accumulate on the station platforms. This standard operating problem of a slower train causing the following trains to speed up is referred to as “bunching.”

Bunching results in some trains being significantly more crowded than others. The effects of bunching do not balance out: the aggravation of waiting longer for a crowded train more than counterbalances any satisfaction of a short wait for less crowded train. Commuters tend to be in a hurry and often will try to push their way onto a crowded train rather than trust that another train is right behind. Because more passengers are carried in the more crowded trains, statistically more riders likely would end up on the crowded trains. In a recent study, *Measuring the Impacts of Transit Reliability on Transit Ridership*³, the unpredictability of wait times on the MBTA’s rapid transit lines was shown to increase the perceived travel times that riders consider when choosing a travel mode.

Not only does bunching cause crowding but also crowding causes bunching. Any delay can set in motion the bunching process. As shown in Table 14, crowding increases the amount of time required for riders to leave and enter a train. If a transit line has ample carrying capacity, it can accommodate a certain amount of variation in station boardings. If the transit line is operating without any reserve capacity, then even small increases in boardings at a particular station might throw the train off schedule and begin the bunching process.

5.4 Peak-Period Crowding on the Rail Rapid Transit Lines

Developing Crowding Data

For the *Impacts of Transit Reliability* study, the number of trains was observed by 15-minute interval on each line and direction for all 21 weekdays in May 2011, and these observations formed the dataset with which the capacity statistics for this study were developed. Appendix D shows the average number of weekday trains by 15-minute peak-period interval that operated during these 21 weekdays.

These data were then used to calculate of the number of trains that operated between every pair of rapid transit stations with faregates by 15-minute interval for each of the 21 weekdays. Averaging the numbers trains between each station-pair gives an estimate of the amount of train service between each station-pair on a usual weekday by 15-minute interval.

³ *Measuring the Impacts of Transit Reliability on Transit Ridership*, Boston Region MPO, July 2013.

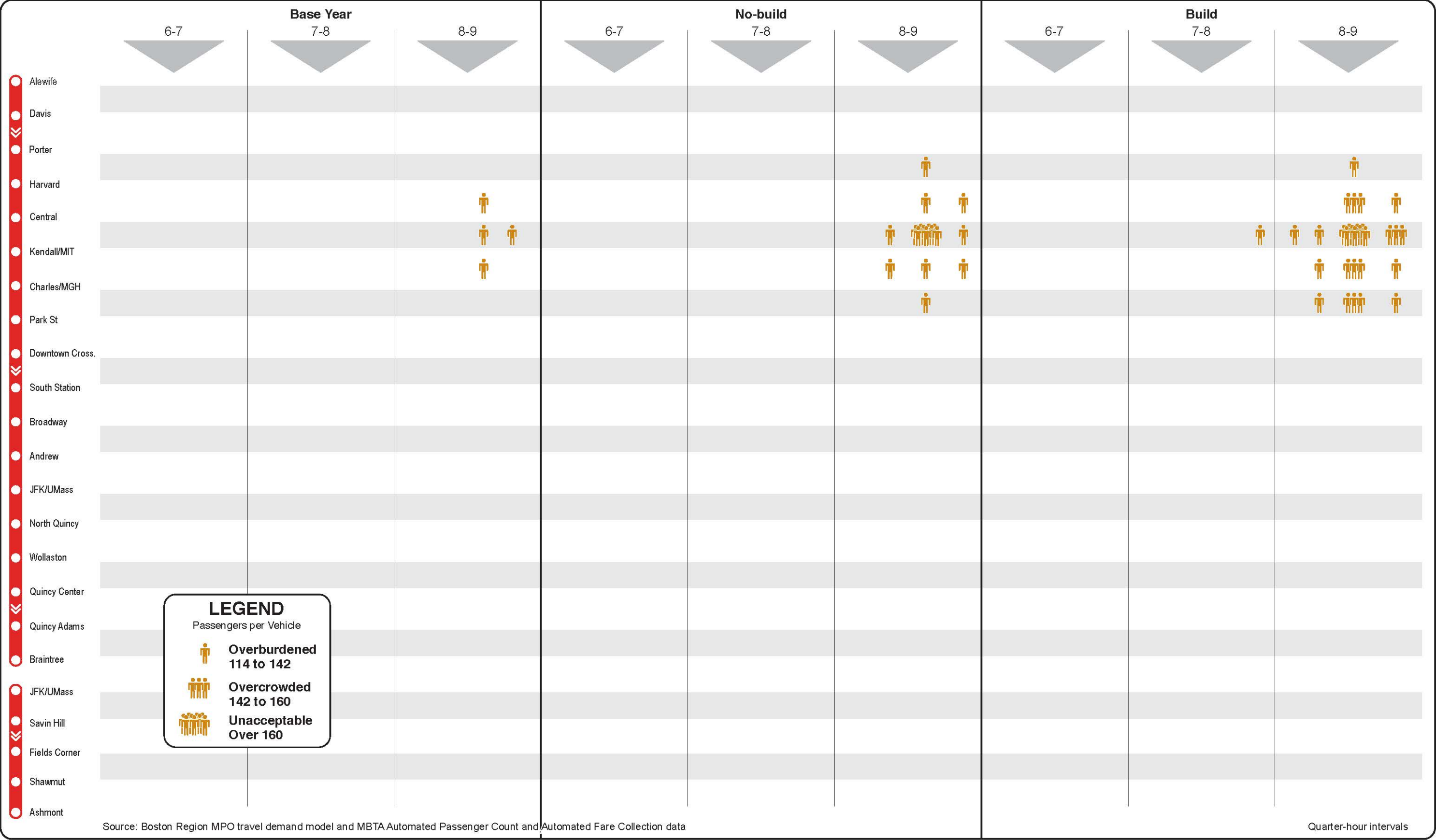
The numbers of riders entering these stations by 15-minute interval can also be known because of the electronic faregates, and data and analytical methods exist to estimate the portion of riders boarding trains in each available direction and the most probable exit stations. Staff performed this analysis for all system ridership for one day in 2011, and calculated average boardings and alightings for a typical weekday by station, direction, and 15-minute interval. From these data the total number of passengers traveling over a segment was calculated for every pair of stations with faregates during every 15-minute interval during the AM and PM peak periods. These ridership data are summarized in Appendix E.

Dividing the total number of passengers expected to be riding between a station-pair during a 15-minute interval by the number of transit vehicles expected to serve the station-pair during the same interval gives a number of passengers per vehicle. These passenger-per-vehicle values will indicate the presence of crowding based on the vehicle capacity breakpoints shown in Table 15. Detailed information about Base Year passenger loads by station-pair and 15-minute interval are found in Appendix F.

Visualizing Rapid Transit Crowding

Transit vehicle crowding is depicted graphically for the Base Year and the 2040 No-build and Build scenarios for each of the rail rapid transit lines in a set of 16 graphics, Figures 7 through 22. Each of the four rail rapid transit lines has a set of four figures, two depicting AM peak crowding (one figure for each direction) and two depicting PM peak crowding. The content and organization of these graphics may be illustrated using the Red Line, Figures 7–10, as an example.

Figure 7 shows crowding on Red Line trains originating in Alewife and ending at either Braintree or Ashmont stations during the AM peak period, for the three hours between 6:00 and 9:00 AM. The Red Line and its stations are shown on the left, with the north-most station, Alewife, appearing at the top. The Red Line operates over two branches; the branch between JFK/UMass and Ashmont is shown separately near the bottom of the figure.



BOSTON
REGION
MPO

Figure 7
Red Line AM Peak Crowding:
Alewife to Braintree/Ashmont

Core
Capacity
Constraints

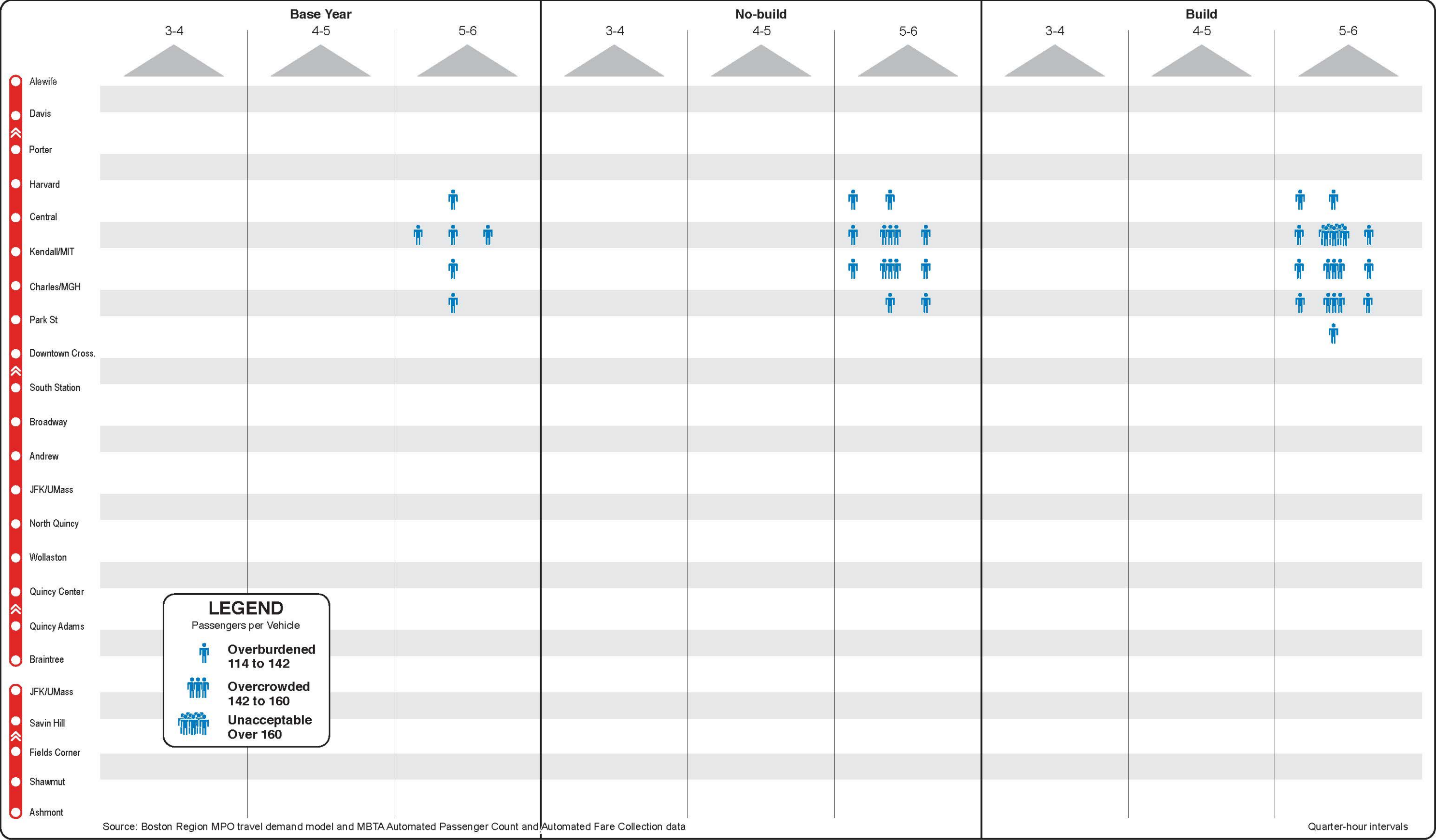


Figure 8
Red Line PM Peak Crowding:
Ashmont/Braintree to Alewife

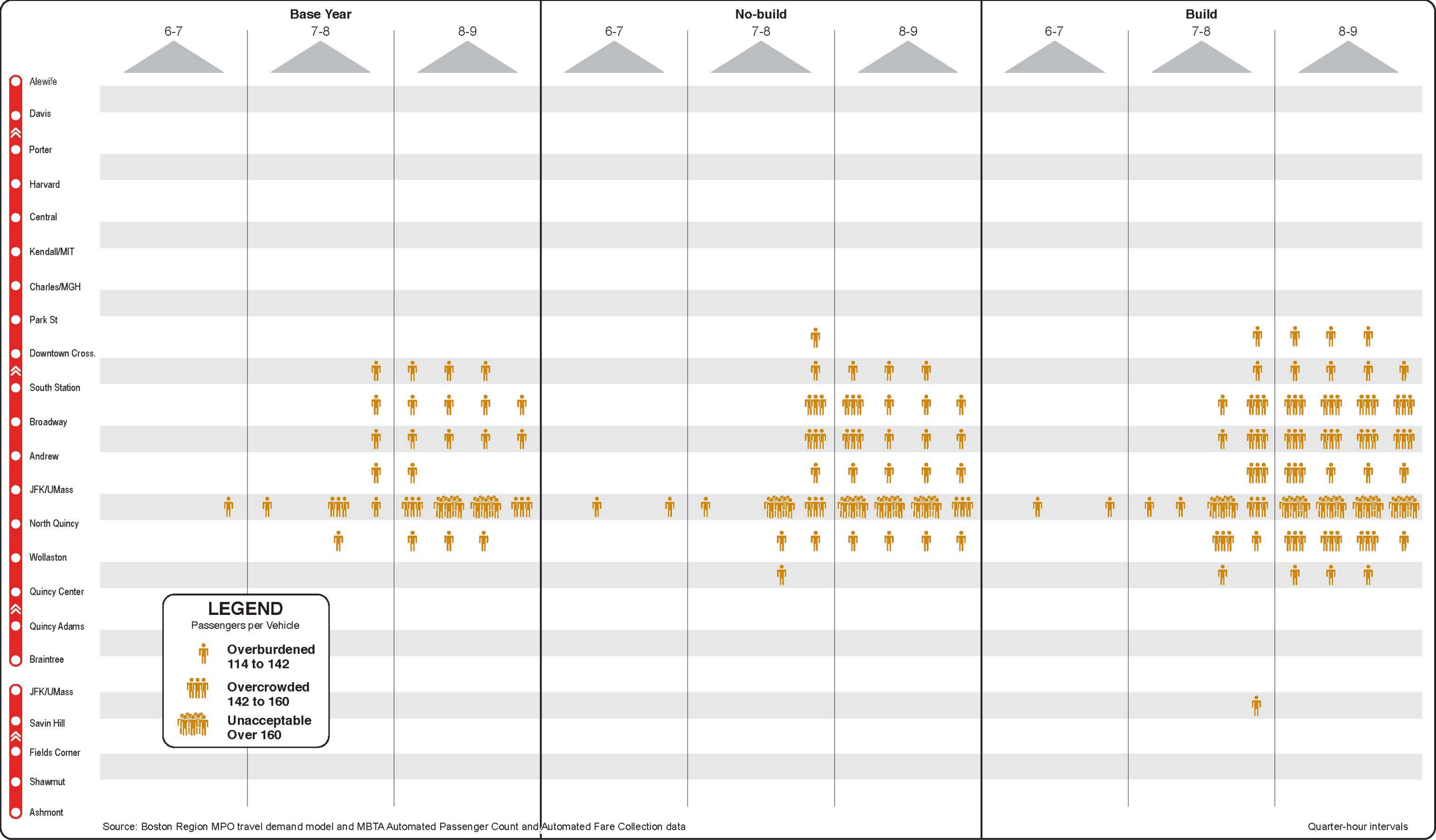
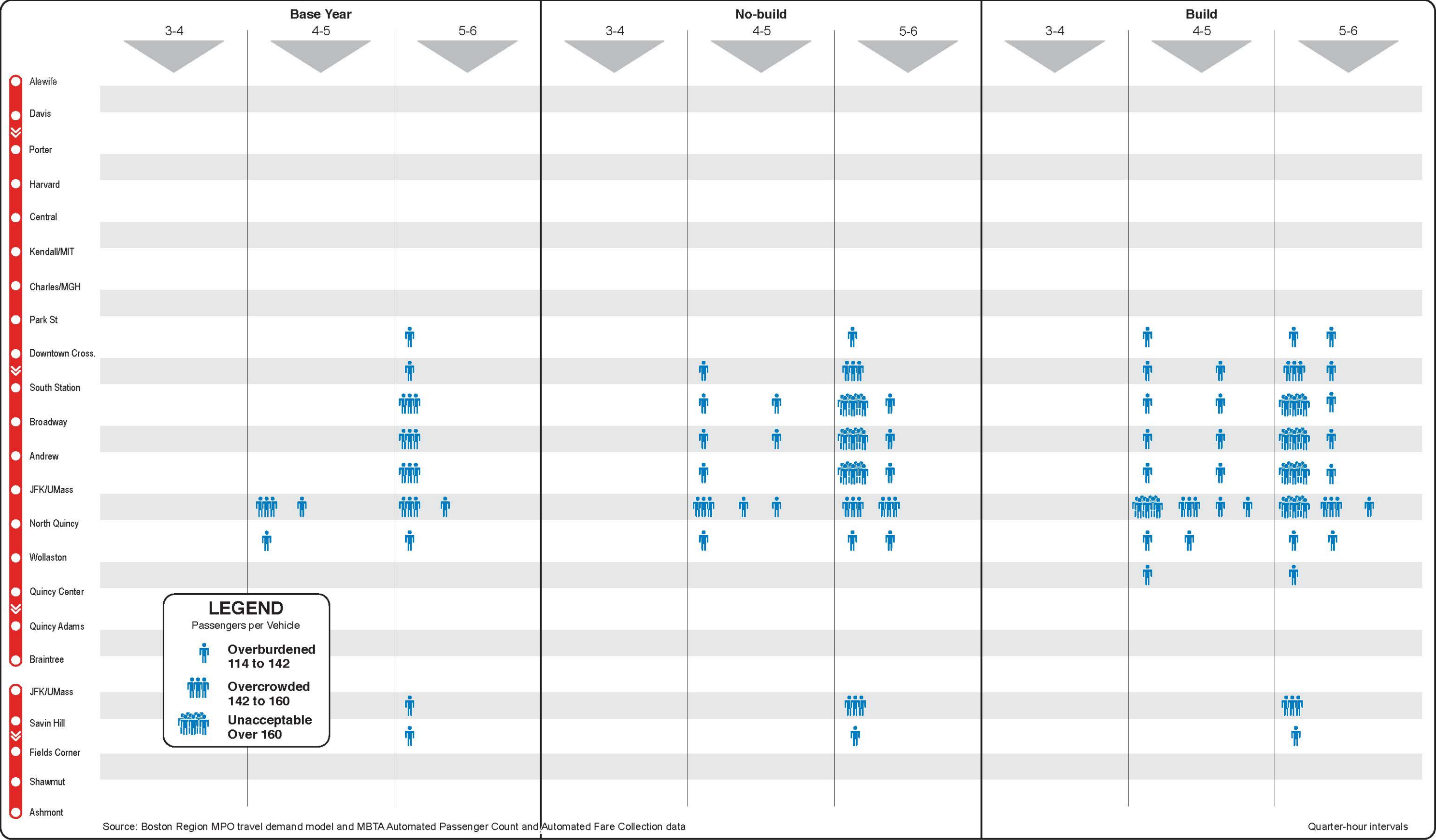


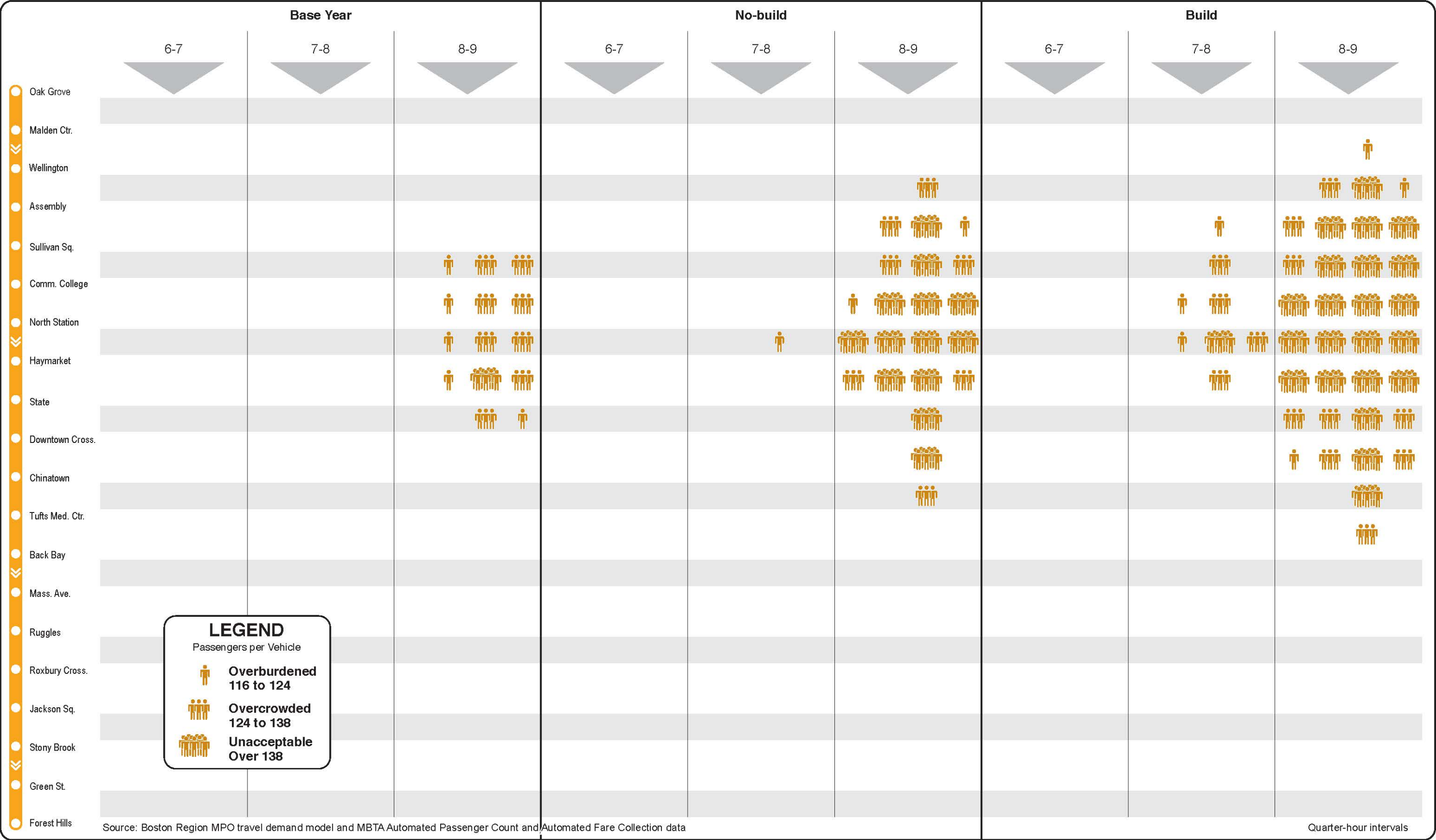
Figure 9
Red Line AM Peak Crowding:
Ashmont/Braintree to Alewife



BOSTON
REGION
MPO

Figure 10
Red Line PM Peak Crowding:
Alewife to Braintree/Ashmont

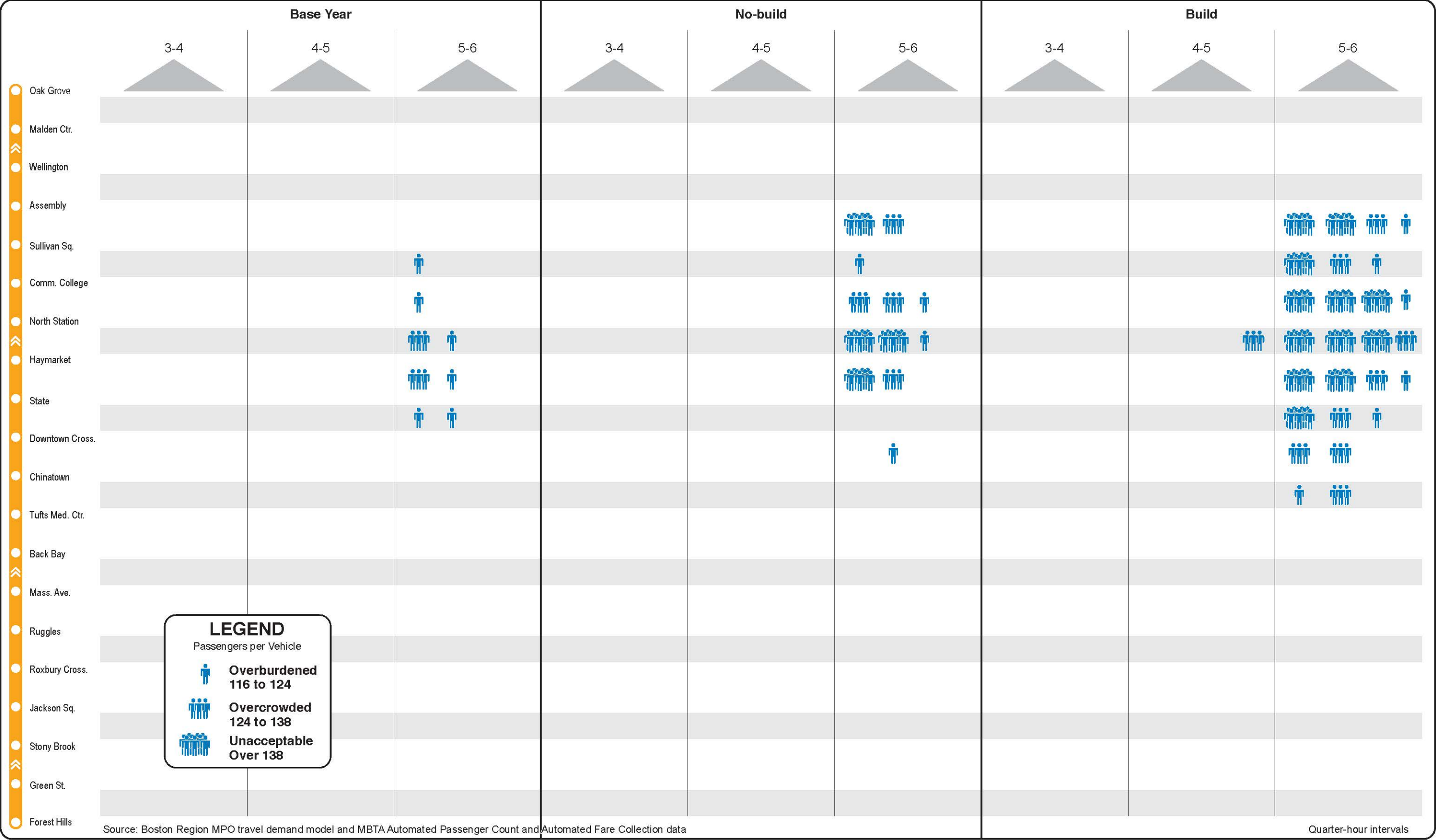
Core
Capacity
Constraints



BOSTON
REGION
MPO

Figure 11
Orange Line AM Peak Crowding:
Oak Grove to Forest Hills

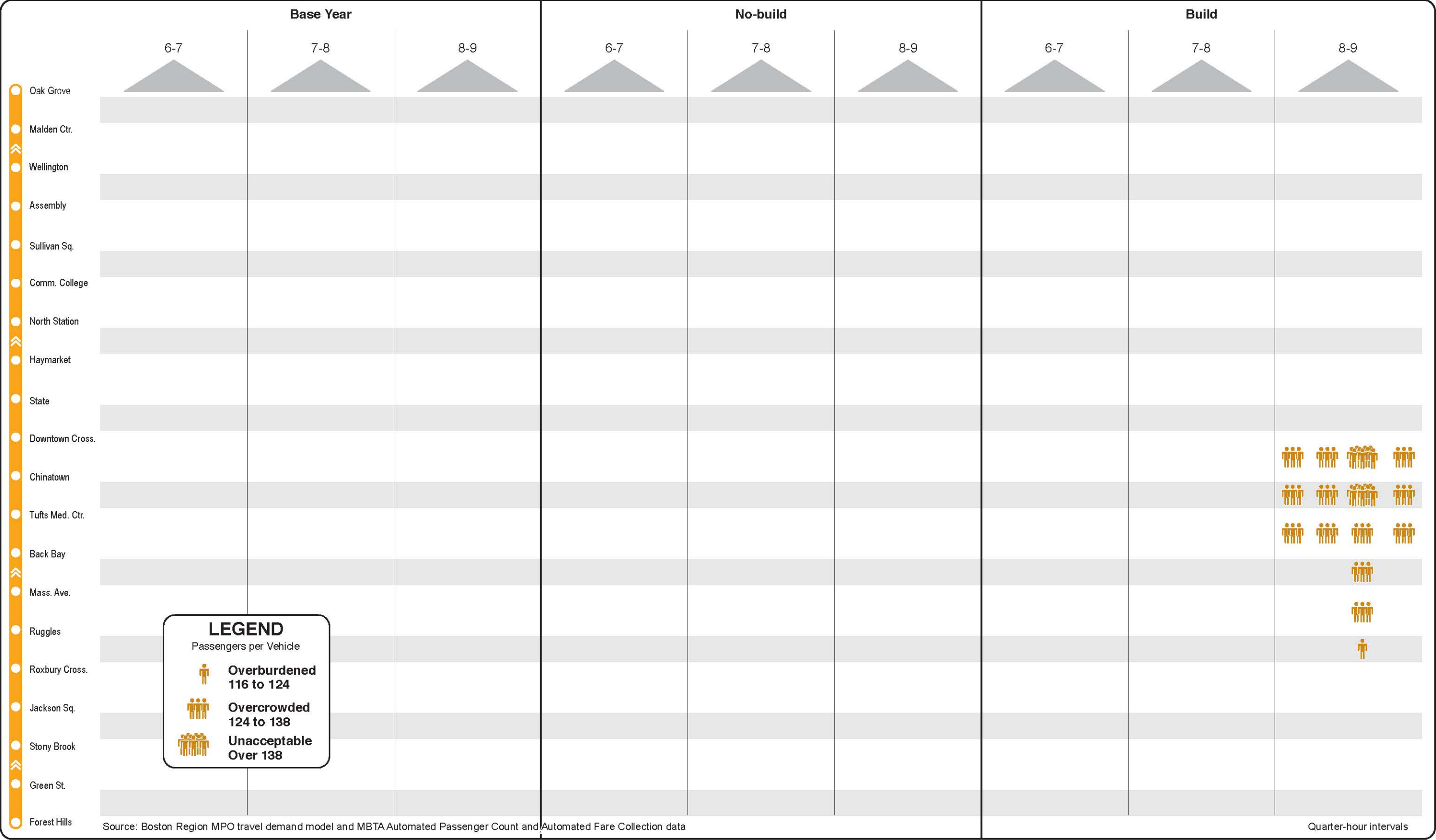
Core
Capacity
Constraints



BOSTON
REGION
MPO

Figure 12
Orange Line PM Peak Crowding:
Forest Hills to Oak Grove

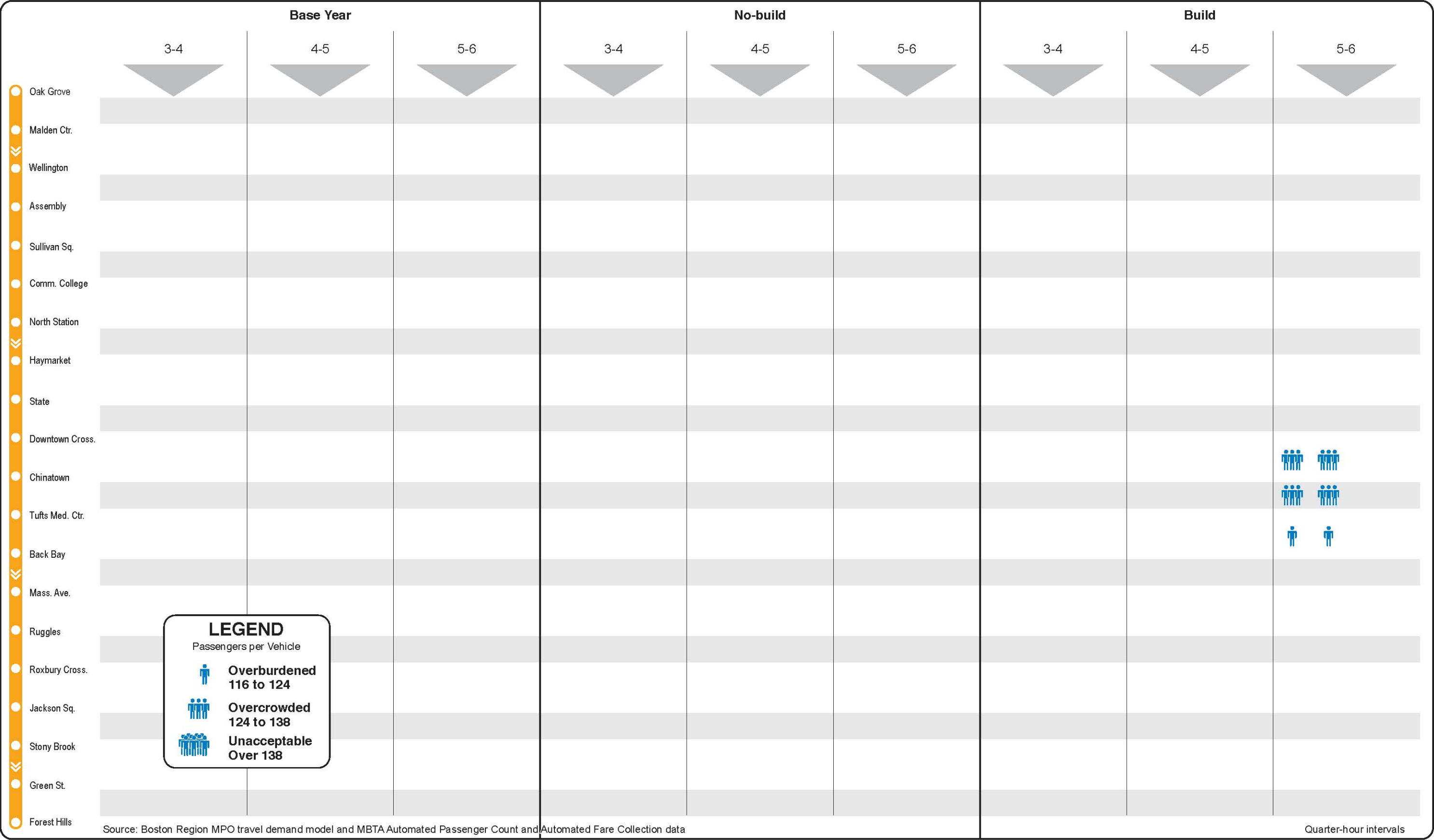
Core
Capacity
Constraints



BOSTON
REGION
MPO

Figure 13
Orange Line AM Peak Crowding:
Forest Hills to Oak Grove

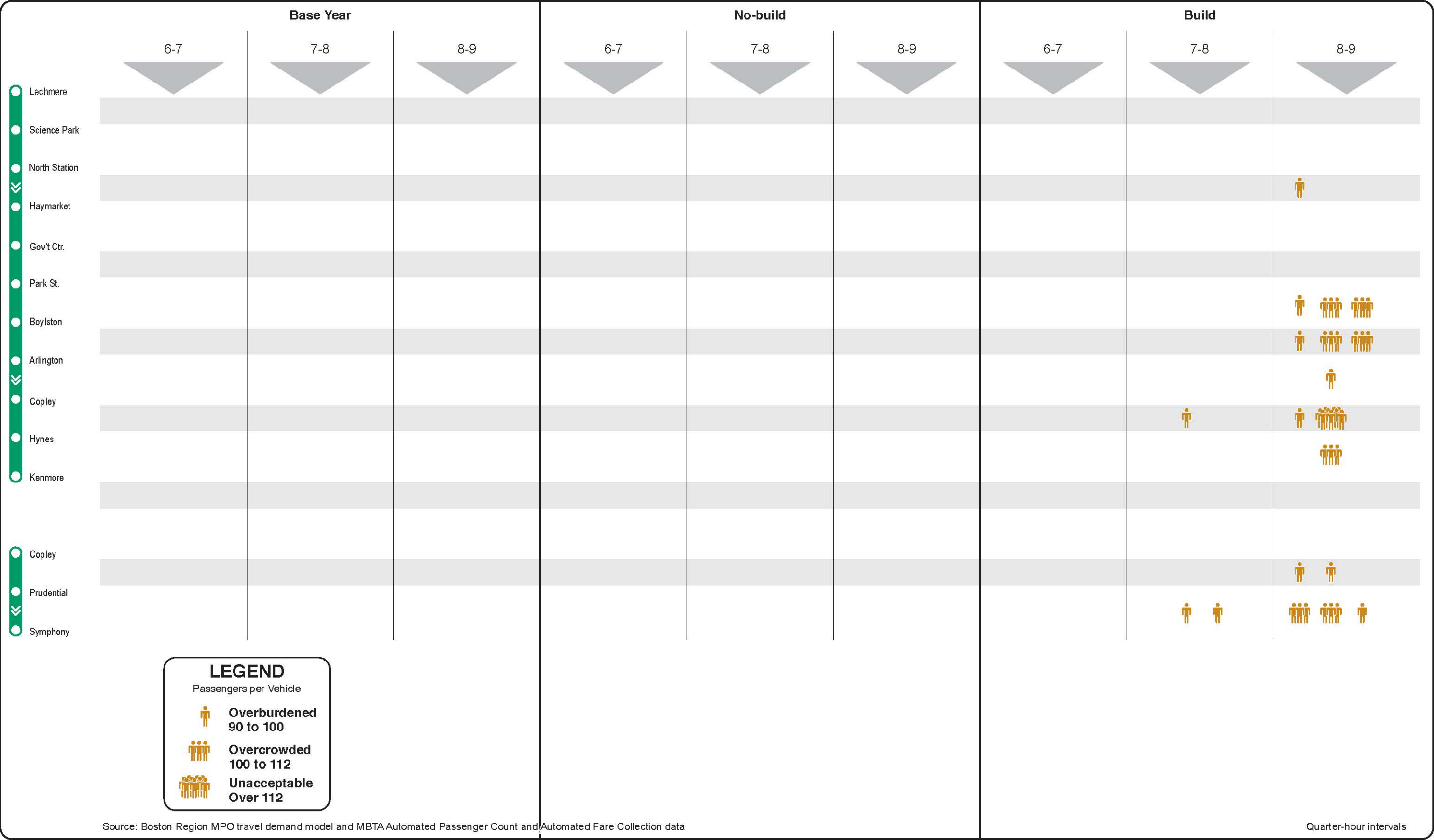
Core
Capacity
Constraints



BOSTON
REGION
MPO

Figure 14
Orange Line PM Peak Crowding:
Oak Grove to Forest Hills

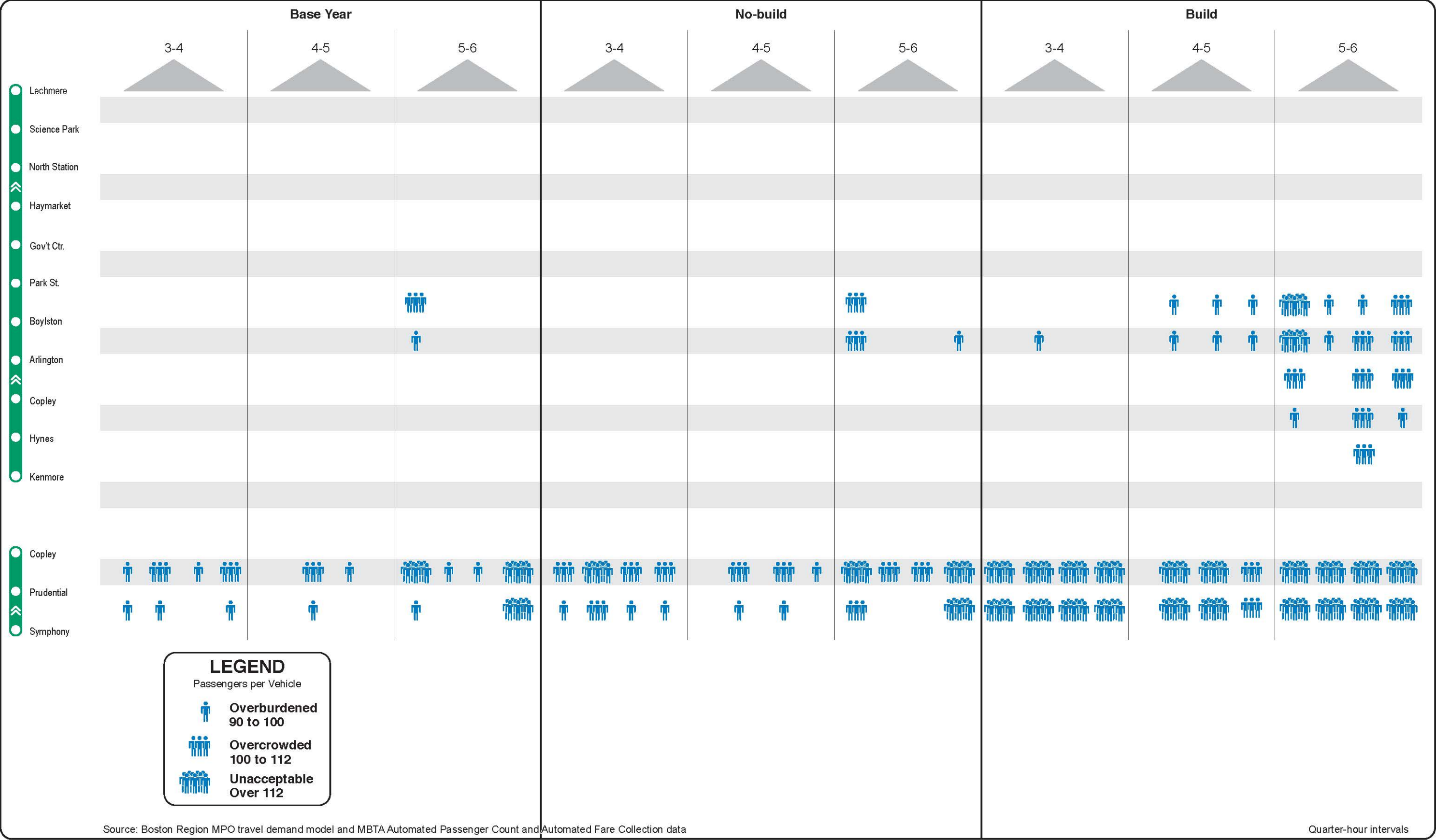
Core
Capacity
Constraints



BOSTON
REGION
MPO

Figure 15
Green Line AM Peak Crowding:
Lechmere to Kenmore/Symphony

Core
Capacity
Constraints

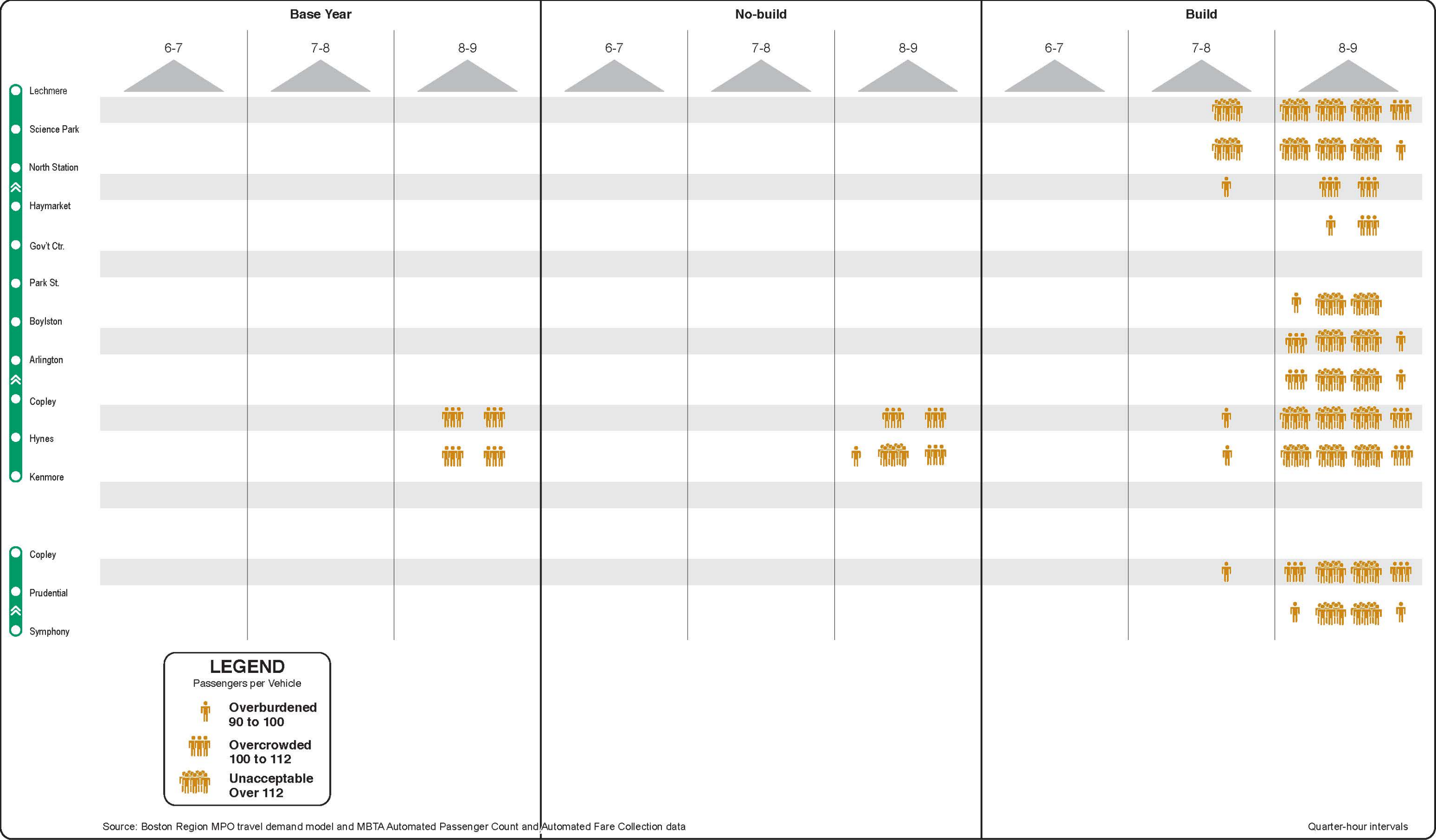


BOSTON
REGION
MPO

Figure 16

Green Line PM Peak Crowding:
Symphony/Kenmore to Lechmere

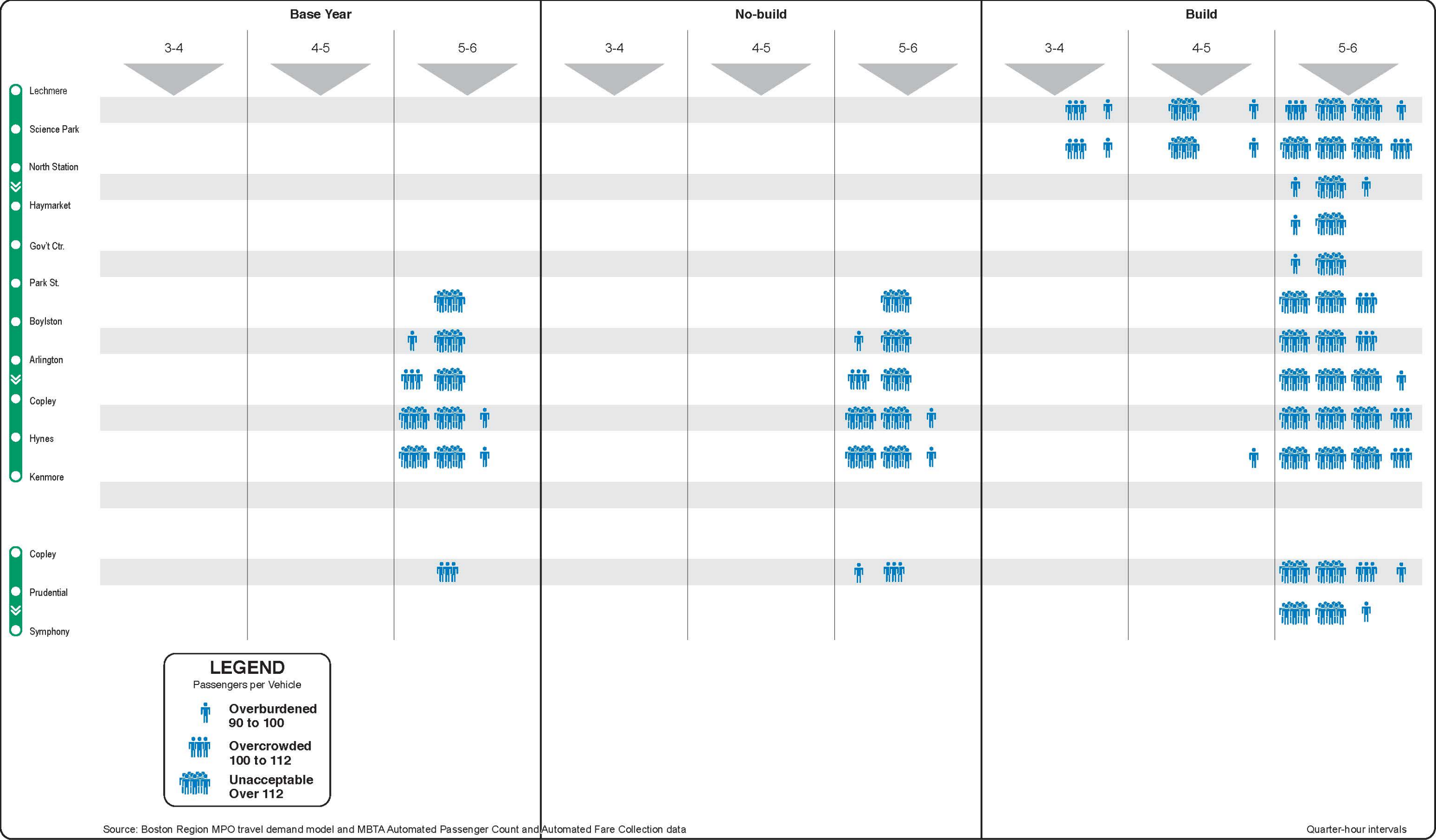
Core
Capacity
Constraints



BOSTON
REGION
MPO

Figure 17
Green Line AM Peak Crowding:
Symphony/Kenmore to Lechmere

Core
Capacity
Constraints



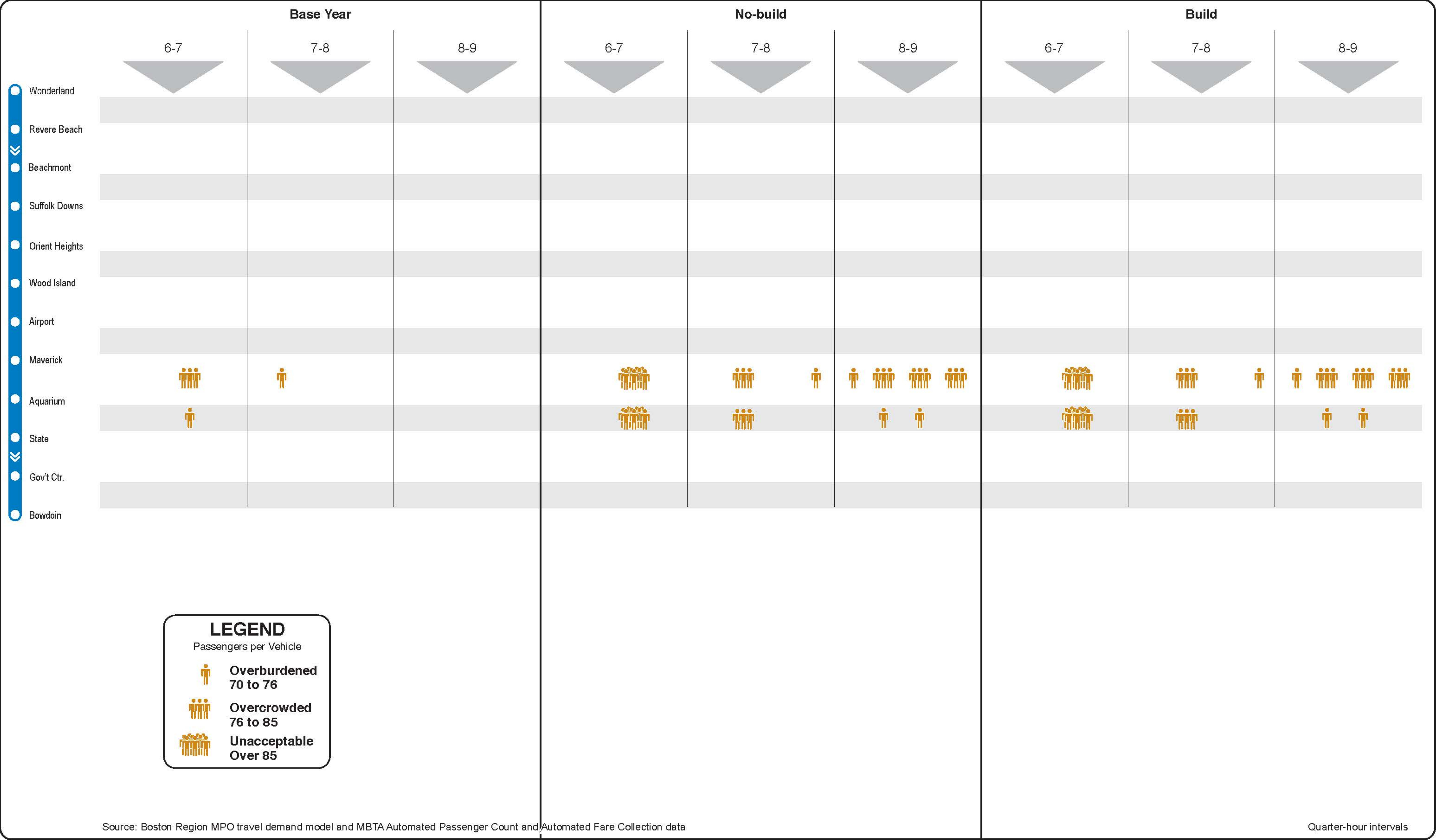
BOSTON
REGION
MPO

Figure 18

Green Line PM Peak Crowding:

Lechmere to Kenmore/Symphony

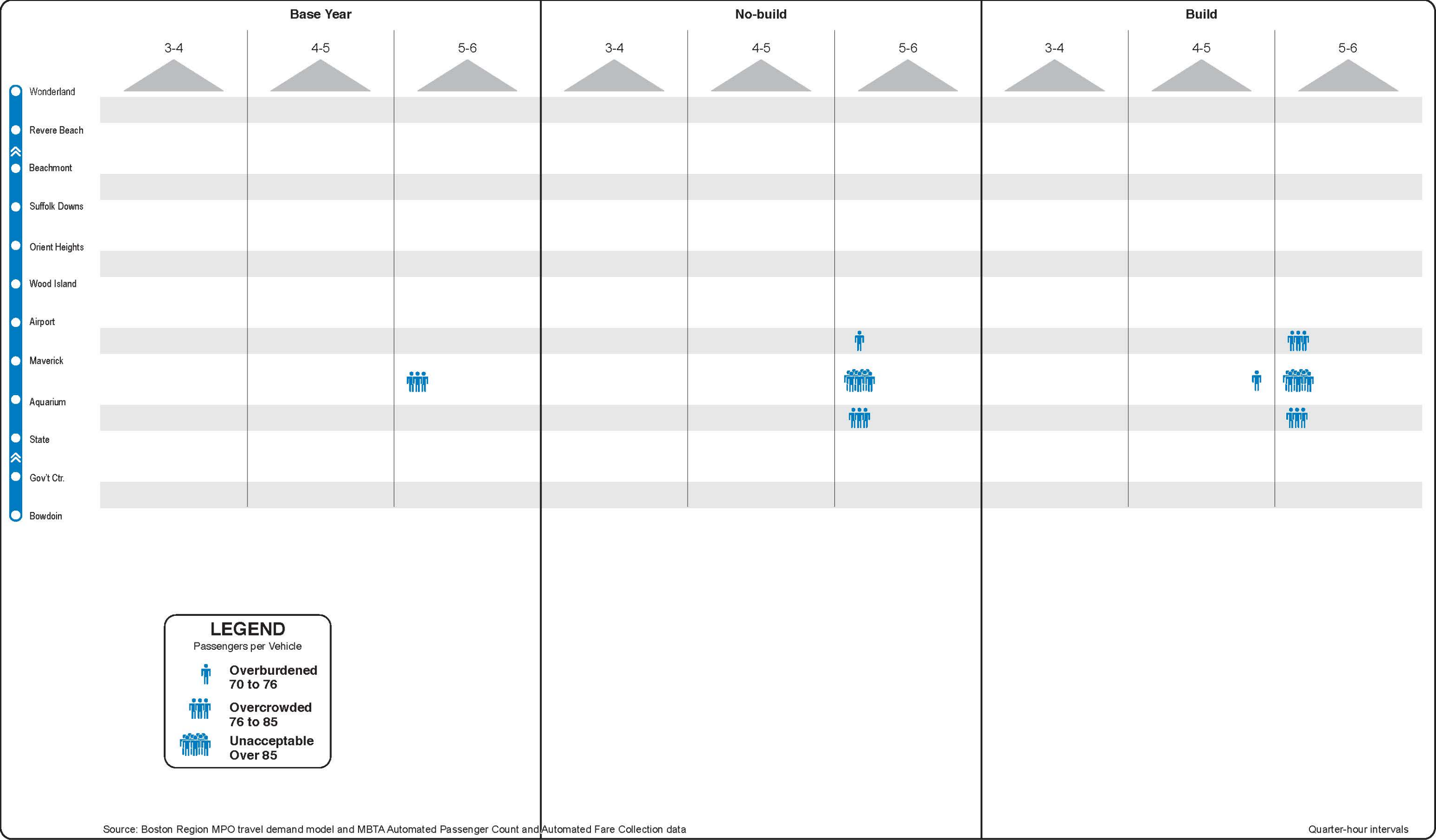
Core
Capacity
Constraints



BOSTON
REGION
MPO

Figure 19
Blue Line AM Peak Crowding:
Wonderland to Bowdoin

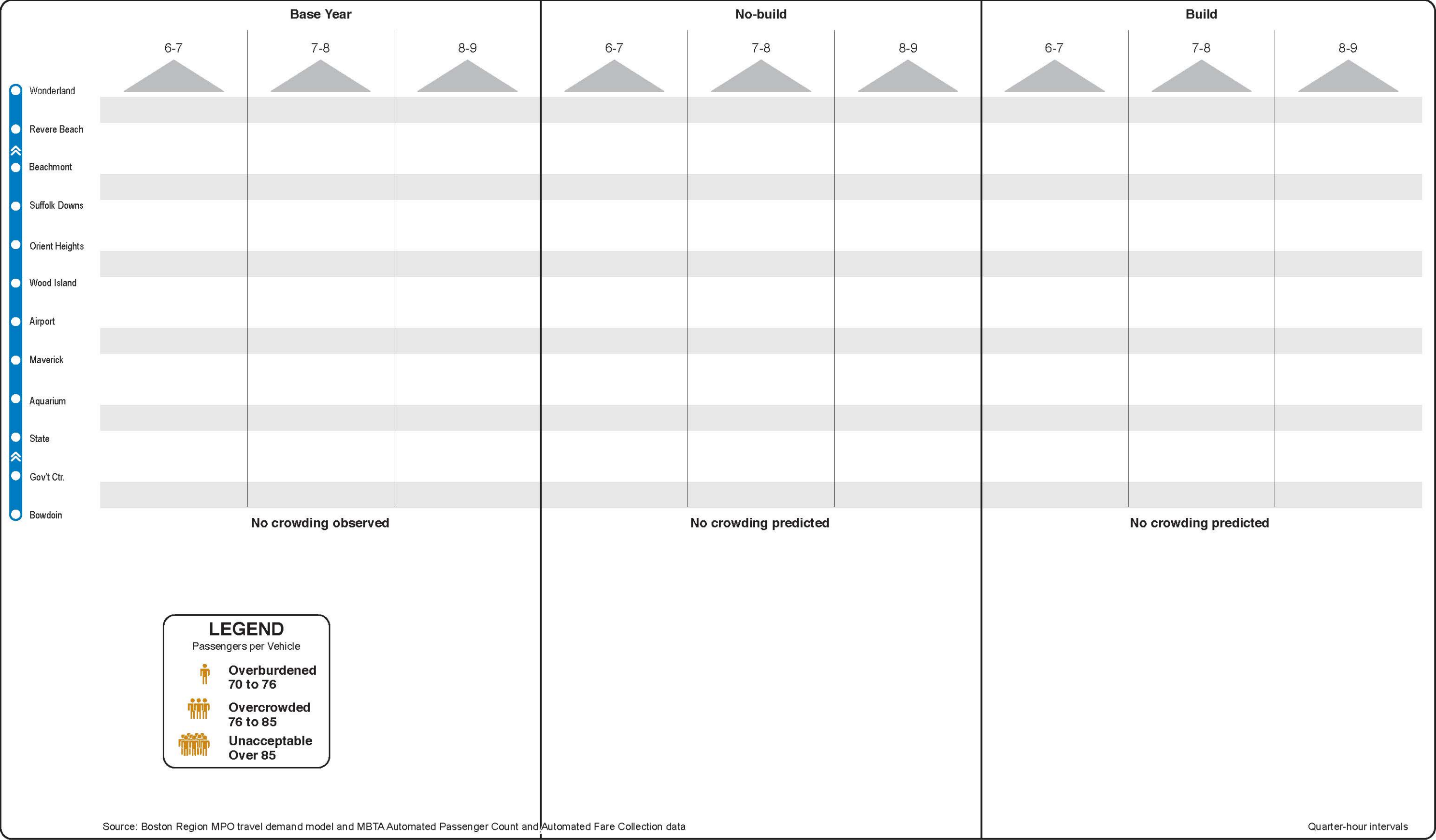
Core
Capacity
Constraints



BOSTON
REGION
MPO

Figure 20
Blue Line PM Peak Crowding:
Bowdoin to Wonderland

Core
Capacity
Constraints



BOSTON
REGION
MPO

Figure 21
Blue Line AM Peak Crowding:
Bowdoin to Wonderland

Core
Capacity
Constraints

The three scenarios, Base Year, No-Build and Build appear at the top. The three AM peak-period hours are shown below each scenario name, and beneath the hours, there are arrows indicating the direction of travel. Alewife station appears at the top of all Red Line figures, but the direction of travel, indicated by the arrows, is away from Alewife in Figures 7 and 10 and towards Alewife in Figures 8 and 9.

Within each one-hour column are four positions where a crowding icon might be placed. The crowding icons are shown in the legend and indicate levels of crowding specific to Red Line vehicles as defined in Table 15. For instance, in the Base Year for travel between Central and Kendall/MIT crowding is apparent, with more than 114 passengers per vehicle between 8:30 and 8:45 AM, and between 8:45 and 9:00 AM. Two icons indicating “Overburdened” are placed in these two positions.

More crowding icons appear between 8:00 and 9:00 AM in the No-Build scenario, reflecting substantial regional growth and a large increase in Red Line ridership, as shown in Table 13. In this scenario, crowding between Central and Kendall/MIT begins at 8:15 AM, and between 8:30 and 8:45 AM there are more than 160 passengers per vehicle, indicated by the “Unacceptable” crowding icon. Detailed information about 2040 No-Build scenario passenger loads by station-pair and 15-minute interval are found in Appendix G.

The Build scenario includes trips generated by the 72 large-impact projects in the 20 sample TAZs. Both the duration and severity of AM congestion in this direction are greater than in the No-Build scenario; and the “Overcrowded” icon appears, indicating that the average vehicle is carrying more passengers than the “acceptably full” level shown in Table 15. Detailed information about 2040 Build scenario passenger loads by station-pair and 15-minute interval are found in Appendix H.

Figure 8 functions as a companion graphic to Figure 7. It shows PM peak-period congestion in the opposite direction as Figure 7, suggesting congestion on the homebound leg of a daily commute. The times at the top of the figure show the three hours between 3:00 and 6:00 PM, and the arrows indicate that the travel is towards Alewife. In addition, the color of the crowding icons changes from ochre (for AM) to azure (PM). Analysis and implications of Red Line crowding are discussed in a later section that considers the individual rapid transit lines.

Figure 9 shows AM peak crowding but in the direction from Braintree and Ashmont towards Alewife as indicated by the direction of the arrows at the top of the figure. Figure 10 shows PM peak crowding in the return direction with the

arrows pointing away from Alewife. The figures for the other three rapid transit lines are organized in the same manner as for the Red Line.

Apparently Random Crowding

There are instances in Figures 7 through 22 where crowding seems to jump way up or totally disappear for no obvious reason. At some stations, especially those where major transit services intersect, a big change in crowding is to be expected. At other locations, the change in crowding seems out of proportion to the importance of the station. Similarly, big changes in crowding are seen between adjacent 15-minute intervals.

To the extent practicable, the MBTA attempts to dispatch rapid transit trains according to predetermined schedules. As a weekday peak period progresses, some deviation from the schedule becomes inevitable. By averaging the number of trains between station-pairs over a month, this analysis comes closer to approximating service with the intended train frequencies. Even then, crowding levels at some station-pairs and time periods do not seem to have a clear explanation.

This randomness in a sense represents a finding of this study. Some of the apparently random crowding patterns identified for the Base Year may have causes such as arrival schedules of connecting services or the influence of the distance between stations, but these causes may not be clear at this level of analysis. In general, we do not discuss these crowding idiosyncrasies here unless there is a probable and relevant explanation.

The analysis in this study extends the crowding patterns observed in the Base Year to the two 2040 transit ridership scenarios. Accommodating substantially increased ridership with essentially the same capacity inevitably will increase crowding, but the crowding idiosyncrasies in 2040 could very well be at different station-pairs and times.

Another random effect is the day-to-day variation in crowding. The crowding shown in Figures 7 through 22 is based on average station-pair frequencies calculated using all 21 observed weekdays. Staff noticed significant day-to-day variation in crowding for individual station-pairs within the 21-day ample period.

Red Line

Transit users board and alight at numerous combinations of Red Line stations throughout the day and in both directions. However, because of strong radial commuting patterns, the Red Line experiences crowding on trains as they

approach downtown stations during the AM peak period, and as they leave these stations during the PM peak period.

The importance of the downtown stations invites consideration of the Red Line as two interconnected but distinct systems. The northern section brings commuters from the northwest including Cambridge, Somerville, and Arlington to Boston in the morning and returns them home in the evening. The southern section brings commuters from the southeast including South Boston, Dorchester, Milton, Mattapan, Quincy, and Braintree into Boston in the morning and returns them home in the evening. Current and projected crowding that the north-side commuters might experience is shown in Figures 7 and 8, and crowding that south-side commuters might experience is shown in Figures 9 and 10.

Northern Section

Figure 7 shows that, in the Base Year during the last hour of the AM peak period, the Red Line is overburdened between Harvard and Charles/MGH for one 15-minute period. This mild crowding condition continues for a second 15-minute interval in the segment between Central and Kendall/MIT. The Red Line has the largest vehicles in the MBTA's fleet, and has been operating six-car trains since the 1980s (see Table 16). Consequently, the Red Line is well positioned to accommodate future growth in this particular commuting market. Crowding during the PM peak period for the reciprocal trip home (Figure 8) shows moderate patterns similar to AM peak-period crowding.

As seen in Figure 4, none of the selected 72 large-impact developments modeled in the Build scenario is on the northern section of the Red Line. Nevertheless, congestion is predicted to increase in the Build scenario. These added riders could be residents living near the northern section and using the Red Line to reach one of the large-impact developments elsewhere on the rapid transit system. Alternatively, new riders might live in a large-impact development and be traveling to existing job locations in Cambridge or Somerville.

Southern Section

Crowding is a greater problem on the southern part of the Red Line, as seen in Figures 9 and 10. The southern section of the Red Line divides into two branches south of the JFK/UMass station. Only about half of the peak-period trains serve the five stations on the Braintree branch and the four stations on the Ashmont branch. The Red Line's full capacity is only available north of the junction of the two branches at JFK/UMass station.

The crowding that results from operating on two branches is shown in Figure 9. In addition to having one more station than the Ashmont branch, all five Braintree

branch stations were built with large parking facilities, and the line has substantially more ridership than the Ashmont branch. Even in the Base Year, the Braintree branch trains that leave Wollaston Station are overburdened for about an hour, and there is crowding between North Quincy and JFK/UMass for most of the AM peak period, a half-hour of which is at the “unacceptable” level.

Based on this analysis, Base-Year crowding virtually disappears north of JFK/UMass, as service is augmented by the much-less crowded Ashmont trains. Admittedly, passengers on crowded Braintree trains will not get out at JFK/UMass simply to transfer to an uncrowded Ashmont train. However, ample total capacity is available to carry any commuters wishing to board an inbound train at JFK/UMass.

North of JFK/UMass, are the heavily used Andrew and Broadway stations in South Boston. Even with the entire Red Line capacity available here, inbound Red Line trains become overburdened for more than an hour after they add passengers at Andrew.

The widespread regional growth projected for the No-Build scenario will add substantial ridership to the Red Line, generally exacerbating the Base-Year crowding patterns. Several of the 72 large-impact projects are near the Red Line and the Build scenario shows further increase in crowding with more than an hour of unacceptable crowding between North Quincy and JFK/UMass. Even the segment of the Ashmont branch north of Savin Hill becomes overburdened on the inbound approach to the junction with the Braintree branch.

The evening peak period for this commuting market is shown in Figure 10. There is pronounced commuter outflow starting at 5:00 PM and Base-Year trains are overcrowded from South Station all the way to Quincy. Even trains on the Ashmont branch are overburdened during this time period.

The regional growth of the No-Build scenario results in an unacceptable level of crowding between South Station and JFK/UMass, and some overcrowded conditions on the Ashmont branch. The added ridership in the Build scenario extends the unacceptable crowding level south of JFK/UMass into Quincy.

The Red Line has operated exclusively with six-car trains since the 1980s, and scheduled frequencies reflect a maximum that is appropriate for safe operations. By the early 2020s, an older generation of vehicles is expected to be replaced with new vehicles, which will have fewer seats and allow for more standees; this would increase slightly the average vehicle capacity numbers shown in Table 15.

Orange Line

Like the Red Line, the Orange Line also serves distinct north- and south-side commuting markets. It also serves transferring Red and Blue Line riders as they commute to Back Bay locations. Figures 11 and 12 show crowding experienced by north-side commuters, and Figures 13 and 14 show south-side crowding.

Northern Section

The northern section of the Orange Line brings commuters from the north including Charlestown, Everett, Somerville, Medford, Malden, and Melrose. Many of these commuters connect with buses, notably at Wellington, Sullivan Square, and Haymarket.

As seen in Figure 11, in the Base Year the Orange Line is overcrowded during the last half hour of the AM peak period between Sullivan Square and Downtown Crossing, and reaches an unacceptable level of crowding between Haymarket and State. Base-Year crowding is much less severe during the PM peak period, as seen in Figure 12.

The widespread regional growth projected for the No-Build scenario will add substantial ridership to the Orange Line, significantly increasing the Base-Year crowding patterns. Crowding will be unacceptable between North Station and Haymarket for an entire hour, and between 8:30 and 8:45 AM between Assembly and Chinatown.

Many of the 72 large-impact projects summarized in Table 5 and shown in Figure 4 will be served directly by the Orange Line. These include Assembly Row, Assembly Square, North Point, West End, Old Boston Garden, Downtown Crossing, and Northeastern University. The combined impacts of these projected developments would impact the Orange Line severely if it is still operating with today's capacity, as depicted Figure 11. Indeed, if peak-period Orange Line capacity is not expanded meaningfully, then more than half of the congested situations in the AM peak period will be congested at the unacceptable level. The reciprocal congestion during the PM peak period mirrors the AM peak congestion but at a slightly lower level of severity, as seen in Figure 12.

The MBTA is planning to procure new Orange Line vehicles jointly with the new Red Line vehicles, which will expand its vehicle fleet by about 25 percent, and vehicle capacity by 10 percent. With better equipment utilization resulting from a much lower average vehicle age, the Orange Line might be able to move 40 percent more passengers during peak periods. This increased capacity will

reduce the duration and severity of crowding greatly, but even this amount of added capacity would not eliminate unacceptable levels of crowding completely.

The Orange Line vehicle fleet could be expanded further and operated safely beyond what is planned currently. However, with a more ambitious expansion program, equipment storage and maintenance capacity also would need to be addressed.

Southern Section

The southern section of the Orange Line brings commuters from the southwest neighborhoods of Boston including the South End, Fort Hill, Mission Hill, and Jamaica Plain. Commuters from Roslindale and Hyde Park can take buses that connect at Forest Hills.

No congestion was observed in this commuting market in the Base Year, and none is projected for the 2040 No-Build scenario. The current amount of Orange Line capacity is sufficient for the traditional neighborhood-to-downtown radial commute in this corridor, and will continue to be adequate with widespread regional growth in the No-Build scenario.

The large-impact projects envisioned in the Build scenario will elevate ridership in this commuting market and unacceptable crowding conditions would develop, especially between Back Bay and Downtown Crossing. This illustrates the regional nature of congestion. Although the large-impact developments would be built mostly at other locations on the Orange Line, scarce peak-period capacity would be exhausted first between Back Bay and Downtown Crossing stations. A lesser amount of congestion also appears in the PM peak period in the Build scenario, as seen in Figure 14.

Green Line

Faregates and the Function of the Green Line

The ridership by time period value used to estimate crowding for this study was developed from faregate data. On the above-ground sections of the four Green Line branches, vehicle access is usually controlled by the driver, sometimes assisted during the AM peak period by station-platform staff. Riders entering vehicles at stations without faregates neither could be tracked nor their numbers estimated, and the crowding depicted in Figures 15 through 18 reflects only the stations with faregates.

Of the four branches of the Green Line, the B, C, and D branches join at Kenmore, the western-most station with faregates. The E branch has two underground stations with faregates, at Symphony and Prudential, north of which

it joins with the other three branches at Copley. Access to all of the Green Line stations east of Copley is controlled by faregates.

The Green Line's faregated section analyzed here connects directly with the other three rail rapid transit lines, and commuter rail at North Station. This faregated section also closely tracks the "high spine" of concentrated Boston development, passing through Government Center and major Back Bay developments before emerging from the tunnels to serve Brighton, Brookline, Newton, and the Huntington Avenue corridor with above-ground stations. These connections and alignment suggest how this part of the Green Line is utilized to move riders in the core area.

The passenger flows suggested by congestion seen in Figures 15 through 18 do not reflect traditional radial commutes, as in the Red and Orange Line analyses. Instead, this part of the Green Line largely is distributing passengers from more distant locations to specific stops in this densely developed corridor. The passengers may have originated on one of the Green Line's four branches, or they may have transferred at Park Street, Government Center, Haymarket, or North Station.

Estimating Crowding with Insufficient Service Data

A significant amount of Green Line crowding goes undetected in these analyses because of limitations in the type of service data that was available. The time of passengers' departure at the outer end of the four branches was recorded, but not the time that they entered the underground system at Kenmore or Symphony stations. The time that the train reversed direction also was not recorded, nor was the time when the train returned to its starting point.

Given the sketchy available service data, the average number of trains per 15-minute interval must be calculated using the times that the trains begin their trips. Train frequency estimates developed from these data will not reflect schedule-adherence difficulties encountered on the lengthy above-ground sections of these lines, or typical train bunching in the subway. These relatively smoothed-out estimates of train headways were used to calculate the crowding conditions in Figures 15 through 18, but it is important to consider that some 15-minute intervals or station-pairs will see many more or fewer trains than others, with corresponding crowding levels.

The available service data also do not accurately reflect the available capacity between Park Street and Lechmere. The Green Line schedules assume that most trains reverse direction at an intermediate station such as North Station or Government Center, rather than at Lechmere, the end of the line. This creates a "pinchpoint," with significantly less service provided beyond the scheduled

turnaround point. This condition is exacerbated by the common operational practice during peak periods to have some inbound trains reverse direction before reaching the scheduled endpoint. These so-called “short turns” are not recorded but have a major impact on available capacity and crowding at that particular location and time interval. Since the number of short turns is not known, the capacity calculations in Figures 15 through 18 assume that the trains provided service to their scheduled endpoints.

Commuting Westbound in the AM Peak and Eastbound in PM Peak Periods

Despite the optimistic capacity and headway assumptions necessitated by the limitations of service data, the crowding analysis presented here still identifies crowding pinchpoints, and locates future capacity challenges. Figures 15 and 16 depict crowding conditions for peak-period commutes on the Green Line coming from the direction of Lechmere in the morning and returning towards Lechmere in the evening.

Figure 15 shows no Base-Year crowding in this leg of these commutes. Most commuters taking the Green Line in this direction would have transferred from another MBTA service such as a bus at Lechmere, commuter train at North Station, the Blue Line at Government Center, or the Red Line at Park Street. Only the E branch trains serve Lechmere in the Base Year, and they provide sufficient capacity, without showing any crowding, to accommodate riders who connect from buses.

Commuters arriving at North Station have a choice of boarding the Orange Line or the Green Line, which is served here by both E and C branch trains. The Orange and Green Line services work as a crowding “safety valve” for the other lines for a number of important destinations between North Station and Northeastern University. If a commuter train arrives and transferring passengers fill a Green Line train, other Green and Orange Line trains will arrive during the 15-minute interval, keeping the average vehicle load down for the entire interval.

All four Green Line branches served Government Center in the Base Year. In combination, these four services represent the total carrying capacity of the Green Line, as calculated in Table 16, the second highest of the four MBTA rail rapid transit lines. This capacity was able to accommodate commuters transferring from the Blue Line at Government Center and the Red Line at Park Street without showing any crowding. The fact that Blue and Red Line commuters can transfer at State and Downtown Crossing largely explains the absence of any crowding in this direction during the AM peak period.

The extension of the Green Line into Somerville is assumed in both the No-Build and Build scenarios, and many riders transferring from buses at Lechmere will

board at the new stations in Somerville instead. The improved service that the extended Green Line will provide is anticipated to increase the total amount of transit ridership in this corridor beyond what would have been expected from demographic and economic growth alone.

To meet this growth, current plans include extending D branch service beyond its present turnaround point at Government Center all the way to College Avenue in Somerville. This change will effectively double the amount of service between Lechmere and North Station and increase service between North Station and Government Center by 50 percent. Inbound service from Lechmere during the AM peak will not experience any crowding, even in the Build scenario. Only at North Station will the combined effects of all the large-impact projects served by the Green Line generate crowding.

The combined effects of the Build scenario developments produce significant crowding west of Park Street, where no added service is planned. In addition to the increased transit mode share from Somerville, large-impact projects throughout the region will be feeding new ridership onto the Green Line at this point, much by way Red Line transfers. Crowding extends throughout this part of the Green Line, including the Huntington Avenue corridor, which is served only by the E branch.

The reciprocal PM peak-period crowding shown in Figure 16 mirrors the AM crowding, but with somewhat more intensity. Even in the Base Year, the E branch is hard pressed during the PM peak period to move commuters out of the Huntington Avenue corridor, including the Prudential Center. A proposed new entrance to the Hynes Convention Center station may offer some of these commuters an attractive alternative to Prudential station.

Figure 16 shows PM peak-period crowding only as far Park Street station. It is mild in the Base Year and No-Build scenarios, and then becomes severe only in the Build scenario. This is optimistic in two respects. First, bunching and associated crowding is a greater problem on the approach to Park Street than is suggested here because the available service data implied reasonably regular headways. Second, short turns during the PM peak significantly reduce capacity north of Park Street station, resulting in both crowding and riders' fear of missing connecting commuter rail trains at North Station. Figure 16 does imply clearly that if all service were operated to its intended endpoint, then PM peak capacity in this direction would be fully adequate.

Commuting Eastbound in the AM Peak and Westbound in PM Peak Periods

The Base-Year AM peak-period crowding shown in Figure 17 reflects a portion of a more traditional suburb-to-downtown commute. Inbound passengers fill trains

operating above ground through residential neighborhoods along the B, C, and D branches. At Kenmore, the three branches join, and the result shown here is 30 minutes of overcrowded conditions between Kenmore and Copley stations.

Unfortunately, because of limited capacity, high-ridership levels and potential bunching on the individual surface lines, vehicles on some lines may be severely crowded by the time they reach Kenmore. The random arrival sequence of trains from the three branches at Kenmore limits the ability of the combined services to minimize crowding during the AM peak period. Figure 17 suggests that crowding ends east of Copley. This reflects the overly optimistic calculation of capacity based on the total number of trains that were dispatched from their western origins during the 15-minute intervals. In fact, some trains remain crowded east of Copley while others remain below the crowding thresholds.

The neighborhoods served by the B, C, and D branches are mature, and the regional growth projected in the No-Build scenario adds little additional congestion. In contrast, the large-impact developments envisioned in the Build scenario are projected to reinforce this commuting pattern strongly. New housing near Kenmore, Symphony, and Prudential stations will add inbound commuters during the AM peak period. At the same time, developments near North Station and the new Green Line stations at Lechmere and in Somerville will significantly increase commuting to jobs at this end of the Green Line.

As in the No-Build scenario, crowding will be most severe as trains approach Copley, after which crowding will gradually diminish as workers alight to reach their work locations. Park is both a destination station and an important transfer point, and with all four branches continuing at least to Government Center, no crowding is projected for this section of the Green Line.

Only three of the branches are planned to operate north of Government Center, and only two branches would go past North Station to Lechmere. This lower service level combined with commuters transferring from the Blue Line at Government Center or the Orange Line at North Station would cause the unacceptable levels of crowding shown north of North Station in the Build scenario.

The reciprocal PM peak-period crowding shown in Figure 18 mirrors the AM crowding but with significantly greater severity. The demands on the Green Line for this commuting leg are so great that even the optimistic crowding calculations necessitated by service data limitations do not smooth out the unacceptable crowding levels experienced in the Base Year west of Park Street after 5:00 PM. In the Build scenario, unacceptable levels of crowding are predicted after

5:00 PM throughout the entire faregated system. The duration of severe congestion will lengthen, especially on the two branches serving Lechmere.

As with the Orange Line, the carrying capacity of the Green Line could be expanded by increasing the size of the vehicle fleet. However, unlike the Orange Line, the frequency of peak-period Green Line trains cannot be appreciably increased because of the current signaling and safety systems. Meaningfully changing the frequencies would require replacing much of the existing signal system at considerable expense in addition to the cost of any additional vehicles.

Instead of increasing frequencies, there is the potential of operating three-car trains over parts of the Green Line system. Each of the four branches has different design and operating characteristics, which strongly influence the suitability of operating three-car trains on the branch. Factors such as the design of rights-of-way used in surface running and the location of vehicle storage for the branches can determine whether three-car trains are appropriate or even feasible. Given these constraints and considerations, there may be potential pairs of service endpoints, possibly at intermediate points in the system, which could readily accommodate three-car trains and alleviate anticipated crowding.

Blue Line

Like the Orange Line, the Blue Line is a single line without branches. However, unlike the Orange Line, it does not extend through downtown, so it only serves a strong flow of radial commuters entering downtown from one direction. There are eight stations serving residential neighborhoods in East Boston and Revere across Boston Harbor from downtown Boston. Almost all commuters start at these neighborhood stations and commute to jobs near the State, Government Center, or Bowdoin stations, or connect with the Orange or Green Lines.

Any crowding on the commute between the cross-harbor neighborhoods and downtown is depicted in Figures 19 and 20. There is very little reverse commuting from downtown to work locations in these neighborhoods and no crowding icons appear in Figures 21 and 22. Airport station serves both the East Boston neighborhood and a large number of passengers using Logan Airport. Travel to and from the airport happens throughout the day, however, and causes no crowding in the reverse-commute direction.

What little inbound crowding that occurs on the Blue Line is mostly on the section between Maverick station in East Boston, under the Boston Harbor, to Aquarium station (Figure 19). Maverick anchors several heavily used bus lines, which results in a large number of transfers to the Blue Line. While Aquarium is not a major destination, enough riders alight there to reduce the crowding level.

It is noteworthy that most of the crowding occurs during the first hour of the peak period, unlike the other lines in which the last AM peak hour is most severely crowded. One theory for this is that a large portion of Blue Line commuters work in trades and services characterized by relatively early workdays.

The region-wide demographic trends are projected to result in crowding throughout the AM peak period. Crowding during the first AM peak hour seen in the Base Year will reach unacceptable levels in 2040. Some level of crowding between Maverick and the Financial District will be experienced for the second and third peak-period hours as well. None of the large-impact projects are served directly by the Blue Line, and Build-scenario crowding will be in the same general range as in the No-Build scenario.

The moderate crowding experienced during the outbound PM peak-period commute (Figure 20) occurs at 5:00 PM, about the time when crowding is most severe on the other rail rapid transit lines. Some increased crowding is expected for the No-Build scenario, with a further increase in the Build scenario. Altogether, Blue Line crowding appears mild when compared with the other lines. This is largely a result of introducing six-car trains in 2007.

5.5 Peak-Period Crowding on Bus Vehicles

Developing Crowding Data

Unlike rapid transit vehicles, buses are designed so that even at periods of peak ridership, most riders will be able to use an available seat. Having some standees is considered normal and acceptable, especially on urban bus routes with relatively short travel distances. The MBTA considers that a maximum acceptable load is 1.4 times the number of seats. If this level of ridership is exceeded on a regular basis, additional peak-period bus trips should be scheduled. This is consistent with an industry-recommended maximum of 1.5 bus riders per seat.⁴

There are practical reasons for limiting the numbers of standees on buses. Buses accelerate, brake, and turn more quickly than rail rapid transit vehicles, impacting the safety and comfort of standees. In addition, most buses only have two doors, with almost all entrances at the door next to the driver and most exits at the rear door. Excessive crowding limits circulation within a bus and can cause delay and exacerbate the bunching problem.

⁴ Transportation Research Board, *Transit Capacity and Quality of Service Manual*, 2013, http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_165ch-05.pdf.

Implementation of automated passenger counting (APC) equipment on an increasing number of MBTA buses has improved the availability of reliable bus ridership data by trip and trip segment. The APC equipment counts both boardings and alightings, making it possible to calculate the number of riders at any point on a bus trip.

Because of the large number of bus routes and bus stops, staff aggregated and organized the APC ridership data differently than for the analysis of crowding on rail rapid lines. The bus services chosen for analysis have been divided into radial and non-radial routes. Base-Year ridership for the radial routes is presented in Tables 17 and 18, for the AM and PM peak periods, respectively, and in Tables 19 and 20 for the non-radial routes. The MBTA bus vehicle services in this sample include the 15 “key routes,” the three crosstown (CT) routes, the four Silver Line (SL) routes, and seven additional heavily used bus routes.

The way that staff derived this data may be seen with a numerical example from the initial entry in Table 17: MBTA bus route 9 operating during the AM peak period from City Point in South Boston to Copley Square in the Back Bay. For one hour during the AM peak period, Route 9 will experience its highest ridership. The peak-period AM hour intervals of the different bus routes can differ from each other and do not necessarily coincide with an exact clock hour.

The first data entry for Route 9 is the number of buses that left City Point during the AM peak hour, in this case 13. The standard number of seats in an MBTA bus is 39; multiplying 13 by 39 equals 507 seats, the total seat capacity available for this route and direction during the AM peak hour. Some routes operate with buses with seating capacities larger or smaller than the standard 39 seats, and these routes are noted with an “L” or an “S,” respectively, next to the number of buses.

Following the total seats is a column labeled “Total Riders.” Over the course of a one-way trip, each of the 13 buses will pick up and drop off riders at the many stops along its route. At some point along the route, each bus will reach its highest load, after which point more passengers will be leaving than entering and the number of passengers on the bus will decline. Each of the 13 buses during this hour will reach its own peak load at some point on the route. The sum of the 13 peak loads appears in Table 17 as Total Riders.

Table 17
Base-Year Bus Vehicle Crowding on Non-Radial Routes,
Peak AM Hour of Each Route

			Total		Total		Riders					Total		Total		Riders	
			No. of	No. of	No. of		per					No. of	No. of	No. of	per		
Route Inbound Start			Buses	Seats	Riders		Seat	Outbound Start			Outbound End	Buses	Seats	Riders	Sea		
9	City Point	Copley	13	507	667	1.32	Copley				City Point	7	273	185	.68		
15	Kane Sq.	Ruggles	15	585	459	.78	Ruggles				Kane Sq.	10	390	113	.29		
16	Forest Hills	Andrew	6	234	215	.92	Andrew				Forest Hills	7	273	252	.92		
21	Ashmont	Forest Hills	7	273	294	1.08	Forest Hills				Ashmont	7	273	240	.88		
22	Ashmont	Ruggles	8	312	323	1.03	Ruggles				Ashmont	8	312	228	.73		
23	Ashmont	Ruggles	12	468	542	1.16	Ruggles				Ashmont	13	507	347	.68		
28	Mattapan	Ruggles	9	513	477	.93	Ruggles				Mattapan	6	342	155	.45		
31	Mattapan	Forest Hills	13	507	455	.90	Forest Hills				Mattapan	12	468	109	.23		
32	Wolcott Sq.	Forest Hills	20	780	787	1.01	Forest Hills				Wolcott Sq.	20	780	539	.69		
39	Forest Hills	Back Bay	14	798	636	.80	Back Bay				Forest Hills	11	627	344	.55		
57	Watertown	Kenmore	15	585	662	1.13	Kenmore				Watertown	11	429	318	.74		
70	Waltham	Central	7	273	277	1.01	Central				Waltham	5	195	206	1.06		
71	Watertown	Harvard	9	279	416	1.49	Harvard				Watertown	9	279	271	.97		
73	Waverley	Harvard	12	372	655	1.76	Harvard				Waverley	10	310	205	.66		
77	Arlington Hgts	Harvard	10	390	368	.94	Harvard				Arlington Hgts	7	273	180	.66		
111	Woodlawn	Haymarket	17	663	712	1.07	Haymarket				Woodlawn	9	351	221	.63		
116	Wonderland	Maverick	8	312	315	1.01	Maverick				Wonderland	9	351	139	.40		
117	Wonderland	Maverick	8	312	306	.98	Maverick				Wonderland	3	117	91	.78		
SL1	Logan	South Station	7	266	183	.69	South Station				Logan	7	266	332	1.25		
SL2	Design Ctr.	South Station	13	611	92	.15	South Station				Design Ctr.	13	611	610	1.00		
SL4	Dudley	South Station	7	399	379	.95	South Station				Dudley	7	399	193	.48		
SL5	Dudley	Downtown Xing	11	627	578	.92	Downtown Xing				Dudley	10	570	290	.51		
Total of Major Routes			241	10,066	9,797	.97	Total of Major Routes				201	8,396	5,566	.66			

L = Large bus (more than 39 seats). S = Small bus (fewer than 39 seats)
Source: Central Transportation Planning Staff.

Table 18
Base Year Bus Vehicle Crowding on Radial Routes
Peak PM Hour of Each Route

Route	Inbound Start	Inbound End	Buses	Total Seats	Total Riders	Riders /Seat	Outbound Start	Outbound End	Buses	Total Seats	Total Riders	Riders /Seat			
9	City Point	Copley	6	234	145	.62	Copley	City Point	9	351	444	1.26			
15	Kane Sq.	Ruggles	7	273	159	.58	Ruggles	Kane Sq.	7	273	241	.88			
16	Forest Hills	Andrew	4	156	155	.99	Andrew	Forest Hills	5	195	206	1.06			
21	Ashmont	Forest Hills	6	234	178	.76	Forest Hills	Ashmont	5	195	210	1.08			
22	Ashmont	Ruggles	5	195	199	1.02	Ruggles	Ashmont	6	234	246	1.05			
23	Ashmont	Ruggles	9	351	269	.77	Ruggles	Ashmont	11	429	411	.96			
28	Mattapan	Ruggles	7 L	399	229	.57	Ruggles	Mattapan	7 L	399	416	1.04			
31	Mattapan	Forest Hills	13	507	212	.42	Forest Hills	Mattapan	13	507	381	.75			
32	Wolcott Sq.	Forest Hills	16	624	393	.63	Forest Hills	Wolcott Sq.	16	624	567	.91			
39	Forest Hills	Back Bay	10 L	570	431	.76	Back Bay	Forest Hills	10 L	570	554	.97			
57	Watertown	Kenmore	7	273	299	1.10	Kenmore	Watertown	9	351	422	1.20			
70	Waltham	Central	7	273	285	1.04	Central	Waltham	7	273	342	1.25			
71	Watertown	Harvard	7 S	217	143	.66	Harvard	Watertown	7 S	217	315	1.45			
73	Waverley	Harvard	12 S	372	227	.61	Harvard	Waverley	12 S	372	536	1.44			
77	Arlington Hgts	Harvard	8	312	177	.57	Harvard	Arlington Hgts	8	312	307	.99			
111	Woodlawn	Haymarket	13	507	376	.74	Haymarket	Woodlawn	15	585	615	1.05			
116	Wonderland	Maverick	4	156	133	.85	Maverick	Wonderland	6	234	225	.96			
117	Wonderland	Maverick	3	117	96	.82	Maverick	Wonderland	4	156	192	1.23			
SL1	Logan	South Station	7	266	348	1.31	South Station	Logan	7	266	259	.97			
SL2	Design Ctr.	South Station	13 L	611	553	.91	South Station	Design Ctr.	7 L	329	102	.31			
SL4	Dudley	South Station	7 L	399	205	.51	South Station	Dudley	7 L	399	235	.59			
SL5	Dudley	Downtown Xing	11 L	627	369	.59	Downtown Xing	Dudley	11 L	627	503	.80			
Total of Major Routes				182	7,673	5,580	.73	Total of Major Routes				189	7,898	7,728	.98

Source: Central Transportation Planning Staff

Table 19
Base Year Bus Vehicle Crowding on Radial Routes
Peak AM Hour of Each Route

Route		Start	End	Buses	Total Seats	Total Riders	Riders /Seat	Start	End	Buses	Total Seats	Total Riders	Riders /Seat		
1	Harvard	Dudley		8	312	346	1.11	Dudley	Harvard	8	312	328	1.05		
47	Central	Broadway		9	351	469	1.34	Broadway	Central	4	156	108	.69		
66	Harvard	Dudley		7	273	364	1.33	Dudley	Harvard	8	312	365	1.17		
86	Sullivan	Reservoir		6	234	208	.89	Reservoir	Sullivan	6	234	299	1.28		
CT1	Central	BU Medical		4	156	172	1.10	BU Medical	Central	4	156	107	.69		
CT2	Sullivan	Ruggles		4	156	197	1.26	Ruggles	Sullivan	4	156	119	.76		
CT3	Beth Israel	Andrew		7	273	29	.11	Andrew	Beth Israel	7	273	183	.67		
Total of Major Routes				45	1,755	1,784	1.02	Total of Major Routes				41	1,599	1,509	.94

Source: Central Transportation Planning Staff

Table 20
Base Year Bus Vehicle Crowding on Non-Radial Routes
Peak PM Hour of Each Route

Route	Start	End	Buses	Total Seats	Total Riders	Riders /Seat	Start	End	Buses	Total Seats	Total Riders	Riders /Seat	
1	Harvard	Dudley	9	351	396	1.13	Dudley	Harvard	9	351	375	1.07	
47	Central	Broadway	4	156	157	1.00	Broadway	Central	5	195	252	1.29	
66	Harvard	Dudley	7	273	309	1.13	Dudley	Harvard	7	273	305	1.12	
86	Sullivan	Reservoir	4	156	186	1.19	Reservoir	Sullivan	4	156	162	1.04	
CT1	Central	BU Medical	3	117	76	.65	BU Medical	Central	3	117	89	.76	
CT2	Sullivan	Ruggles	3	117	112	.96	Ruggles	Sullivan	3	117	157	1.34	
CT3	Beth Israel	Andrew	6	234	134	.57	Andrew	Beth Israel	7	273	59	.22	
Total of Major Routes			36	1,404	1,370	.98	Total of Major Routes			38	1,482	1,398	.94

Source: Central Transportation Planning Staff

Technically, the Total Riders number represents the total number of riders on the 13 buses who were riding when the peak load was reached. Other riders may have both boarded and alighted before or after the peak load was reached, but these riders do not enter into this calculation. In addition, the 13 buses do not necessarily reach the maximum load at the same point on the route. For instance, the route 9 buses tend to have the greatest loads near where they cross the Red Line at Broadway station. Some buses are at their peak when they reach Broadway, and have more alightings than boardings at that stop. Other buses actually pick up more riders at Broadway, and the peak load point for these buses comes after Broadway.

The final element of the crowding analysis is the ratio between Total Riders and Total Seats. In this case, we highlighted the value of 1.32 with salmon-colored shading. Only two levels of crowding are highlighted in these tables. Riders per seat ratios that are greater than 1.25 but less than 1.4 are indicated in salmon, and are referred to here as overburdened. We used dark pink to indicate where crowding exceeds the 1.4 passenger standard, referred to as overcrowded.

The riders per seat ratios used in these tables indicate the general level of peak-period ridership relative to the capacity deployed on these routes. Since loads build and ebb on various parts of these routes, the crowding implied by these statistics will be experienced only on the most heavily patronized stretches of a particular bus route. Conversely, riders do not arrive at bus stops at a uniform rate and buses do not arrive at regular intervals, and some buses will be appreciably more crowded than others will. The “overburdened” crowding standard reflects this: 1.25 riders per seat may not be excessively crowded, but during the peak hour, some individual buses likely would be overcrowded if the route as a whole is overburdened.

Base-Year Bus Vehicle Crowding

The radial bus vehicle services in Tables 17 and 18 are arranged by direction, with the inbound service direction shown on the left halves of the tables and the outbound service direction shown on the right. During the AM peak hour, almost all of the routes have more riders and riders per seat in the inbound than in the outbound direction.

For all but a few routes, the inbound riders and riders per seat are higher in the AM peak than during the PM peak period. Conversely, during the PM peak the outbound routes shown on the right side of Table 18 have, with only two exceptions, more riders than their inbound counterparts on the left side of the table. The major exception to the strong AM inbound and PM outbound pattern is the pair of Silver Line Waterfront routes, SL1 and SL2, that distribute commuters

connecting with the Red Line and commuter Rail at South Station to the growing South Boston Waterfront employment centers.

The only other exception to the stronger AM peak-period inbound ridership pattern is route 16 between Forest Hills and Andrew stations. It has the highest peak-hour ridership in the direction from Andrew to Forest Hills during both the AM and PM peak hours. The AM outbound peak crowding is caused by large numbers of trips to schools near the Forest Hills end of the route. The PM peak period is also strong in that direction because of conventional outbound work trips, which occur later than the PM school trips. Also of note is the fact that Route 70 is more crowded during the AM peak hour outbound than inbound. This is because only five buses operate outbound compared with seven buses inbound. Inbound ridership is still stronger on this route.

Seven bus routes included in this analysis are characterized as being non-radial routes, and Base-Year ridership for these routes is presented in Tables 19 and 20 for the AM and PM peak periods, respectively. Total seats, total riders, and riders per seat are calculated in the same manner as for the radial routes. These tables differ in organization from Tables 17 and 18 in that the left side of the tables shows travel in the counter-clockwise direction around downtown Boston, and the right side shows travel in the clockwise direction.

The non-radial services do not show the pronounced change in direction between the AM and PM peak periods. This can be seen by comparing the total of these seven routes' total peak-hour riders with analogous numbers in other tables. The 1,784 riders traveling in the counter-clockwise direction shown in the last row of Table 19 is 18 percent higher than the 1,509 riders traveling in the clockwise-direction. During the PM peak period, these totals are almost identical: 1,370 and 1,398 riders, respectively. In contrast, the 9,797 total inbound riders in the last row of Table 17 exceed the 5,566 outbound riders by 76 percent. Similarly, the outbound PM total at the bottom of Table 18 exceeds its inbound counterpart by 38 percent.

Several of the bus vehicle services in Tables 17 through 20 show some level of crowding. The overcrowded condition is seen only on routes 71 and 73, which use vehicles with only 31 seats. During the AM peak period, the overburdened condition occurs only on radial route 9, discussed above, and on four of the non-radial routes: 47, 66, 86, and CT2. During the PM peak, the overburdened condition occurs again on route 9 and non-radial routes 47 and CT2, as well as radial routes 70 and SL1.

Schedulers of bus systems are able to revise timetables periodically to match available vehicles with drivers in an effort to limit severity of bus crowding during peak periods. The Base-Year crowding calculations reflect this in that the riders per seat ratios in the stronger peak-period direction tend to cluster between the values of 1.00 and 1.30, while the numbers of peak-period buses on each route vary much more widely.

Year 2040 Bus Vehicle Crowding

Staff prepared projections, incorporated into Tables 21 through 24, of bus vehicle ridership for the year 2040. They include calculations of the level of crowding that would occur if the same amount of service as in the Base Year were operated.

Forecasting bus vehicle ridership at the individual route and stop level was beyond the scope of this study. However, recent travel demand forecasts developed in support of MPO and statewide planning efforts suggest a general range of bus ridership growth that might be expected given the assumed long-range demographic and trip-generation trends.

The Total Riders numbers shown in Tables 17 through 20 are projected to increase by either 8, 12, or 16 percent depending on the route. These forecasts assume that all of the projected Build-scenario developments are completed. The Silver Line services have been studied more extensively than the conventional bus routes, and recent modeling suggests that ridership on the Silver Line might increase slightly more than 15 percent (for this study, an increase of 16 percent is assumed).

The 25 conventional bus routes were assigned a ridership increase of either 8 percent or 12 percent based on each route's proximity to the large-impact projects shown in Figure 4, and other high-growth locations such as the former Allston railroad yards. Ridership on 13 of the conventional bus routes is projected to increase by the higher 12-percent level. These include seven radial routes: 9, 39, 57, 70, 111, 116, and 117. All non-radial routes except Route 1 also are projected to add 12 percent more riders.

Because the allocation of peak-period bus capacity already approximates the needs of the numerous routes, even the moderate projected bus vehicle ridership increases have the potential to cause or exacerbate crowding on some routes. This can be seen for the AM peak radial bus vehicle services by comparing Tables 21 and 17. Routes 71 and 73, already overcrowded in the Base Year, will need to accommodate eight percent more riders in 2040, with standees on Route 73 almost equaling the number of seats. Route 9 goes from overburdened to overcrowded, and Routes 23 and 57 are shown as overburdened in 2040.

Table 21
Year 2040 Bus Vehicle Crowding on Radial Routes
Peak AM Hour of Each Route

Route	Inbound Start	Inbound End	Buses	Total Seats	Total Riders	Riders /Seat	Outbound Start	Outbound End	Buses	Total Seats	Total Riders	Riders /Seat	
9	City Point	Copley	13	507	747	1.47	Copley	City Point	7	273	207	.76	
15	Kane Sq.	Ruggles	15	585	495	.85	Ruggles	Kane Sq.	10	390	122	.31	
16	Forest Hills	Andrew	6	234	233	.99	Andrew	Forest Hills	7	273	272	.99	
21	Ashmont	Forest Hills	7	273	317	1.16	Forest Hills	Ashmont	7	273	260	.95	
22	Ashmont	Ruggles	8	312	349	1.12	Ruggles	Ashmont	8	312	246	.79	
23	Ashmont	Ruggles	12	468	585	1.25	Ruggles	Ashmont	13	507	375	.74	
28	Mattapan	Ruggles	9 L	513	515	1.00	Ruggles	Mattapan	6 L	342	168	.49	
31	Mattapan	Forest Hills	13	507	491	.97	Forest Hills	Mattapan	12	468	118	.25	
32	Wolcott Sq.	Forest Hills	20	780	850	1.09	Forest Hills	Wolcott Sq.	20	780	582	.75	
39	Forest Hills	Back Bay	14 L	798	713	.89	Back Bay	Forest Hills	11 L	627	385	.61	
57	Watertown	Kenmore	15	585	741	1.27	Kenmore	Watertown	11	429	356	.83	
70	Waltham	Central	7	273	310	1.13	Central	Waltham	5	195	230	1.18	
71	Watertown	Harvard	9 S	279	449	1.61	Harvard	Watertown	9 S	279	293	1.05	
73	Waverley	Harvard	12 S	372	707	1.90	Harvard	Waverley	10 S	310	221	.71	
77	Arlington Hgts	Harvard	10	390	398	1.02	Harvard	Arlington Hgts	7	273	194	.71	
111	Woodlawn	Haymarket	17	663	797	1.20	Haymarket	Woodlawn	9	351	247	.70	
116	Wonderland	Maverick	8	312	353	1.13	Maverick	Wonderland	9	351	156	.44	
117	Wonderland	Maverick	8	312	343	1.10	Maverick	Wonderland	3	117	102	.87	
SL1	Logan	South Station	7	266	212	.80	South Station	Logan	7	266	385	1.45	
SL2	Design Ctr.	South Station	13 L	611	107	.17	South Station	Design Ctr.	13 L	611	708	1.16	
SL4	Dudley	South Station	7 L	399	440	1.10	South Station	Dudley	7 L	399	224	.56	
SL5	Dudley	Downtown Xing	11 L	627	670	1.07	Downtown Xing	Dudley	10 L	570	336	.59	
Total of Major Routes			241	10,066	10,822	1.08	Total of Major Routes			201	8,396	6,186	.74

Source: Central Transportation Planning Staff

Table 22
Year 2040 Bus Vehicle Crowding on Radial Routes
Peak PM Hour of Each Route

Route	Inbound Start	Inbound End	Buses	Total Seats	Total Riders	Riders /Seat	Outbound Start	Outbound End	Buses	Total Seats	Total Riders	Riders /Seat			
9	City Point	Copley	6	234	162	.69	Copley	City Point	9	351	497	1.42			
15	Kane Sq.	Ruggles	7	273	172	.63	Ruggles	Kane Sq.	7	273	260	.95			
16	Forest Hills	Andrew	4	156	168	1.07	Andrew	Forest Hills	5	195	223	1.14			
21	Ashmont	Forest Hills	6	234	192	.82	Forest Hills	Ashmont	5	195	227	1.16			
22	Ashmont	Ruggles	5	195	215	1.10	Ruggles	Ashmont	6	234	266	1.14			
23	Ashmont	Ruggles	9	351	291	.83	Ruggles	Ashmont	11	429	444	1.03			
28	Mattapan	Ruggles	7 L	399	248	.62	Ruggles	Mattapan	7 L	399	450	1.13			
31	Mattapan	Forest Hills	13	507	229	.45	Forest Hills	Mattapan	13	507	411	.81			
32	Wolcott Sq.	Forest Hills	16	624	424	.68	Forest Hills	Wolcott Sq.	16	624	612	.98			
39	Forest Hills	Back Bay	10 L	570	482	.85	Back Bay	Forest Hills	10 L	570	620	1.09			
57	Watertown	Kenmore	7	273	335	1.23	Kenmore	Watertown	9	351	473	1.35			
70	Waltham	Central	7	273	319	1.17	Central	Waltham	7	273	383	1.40			
71	Watertown	Harvard	7 S	217	154	.71	Harvard	Watertown	7 S	217	340	1.57			
73	Waverley	Harvard	12 S	372	245	.66	Harvard	Waverley	12 S	372	579	1.56			
77	Arlington Hgts	Harvard	8	312	191	.61	Harvard	Arlington Hgts	8	312	332	1.06			
111	Woodlawn	Haymarket	13	507	421	.83	Haymarket	Woodlawn	15	585	689	1.18			
116	Wonderland	Maverick	4	156	149	.96	Maverick	Wonderland	6	234	252	1.08			
117	Wonderland	Maverick	3	117	107	.91	Maverick	Wonderland	4	156	214	1.37			
SL1	Logan	South Station	7	266	404	1.52	South Station	Logan	7	266	300	1.13			
SL2	Design Ctr.	South Station	13 L	611	641	1.05	South Station	Design Ctr.	7 L	329	118	.36			
SL4	Dudley	South Station	7 L	399	238	.60	South Station	Dudley	7 L	399	273	.68			
SL5	Dudley	Downtown Xing	11 L	627	428	.68	Downtown Xing	Dudley	11 L	627	583	.93			
Total of Major Routes				182	7,673	6,215	.81	Total of Major Routes				189	7,898	8,546	1.08

Source: Central Transportation Planning Staff

Table 23
Year 2040 Bus Vehicle Crowding on Non-Radial Routes
Peak AM Hour of Each Route

Route	Start	End	Buses	Total Seats	Total Riders	Riders /Seat	Start	End	Buses	Total Seats	Total Riders	Riders /Seat	
1	Harvard	Dudley	8	312	373	1.20	Dudley	Harvard	8	312	354	1.14	
47	Central	Broadway	9	351	525	1.50	Broadway	Central	4	156	121	.78	
66	Harvard	Dudley	7	273	408	1.49	Dudley	Harvard	8	312	408	1.31	
86	Sullivan	Reservoir	6	234	233	.99	Reservoir	Sullivan	6	234	335	1.43	
CT1	Central	BU Medical	4	156	193	1.23	BU Medical	Central	4	156	120	.77	
CT2	Sullivan	Ruggles	4	156	221	1.42	Ruggles	Sullivan	4	156	133	.85	
CT3	Beth Israel	Andrew	7	273	33	.12	Andrew	Beth Israel	7	273	205	.75	
Total of Major Routes			45	1,755	1,985	1.13	Total of Major Routes			41	1,599	1,677	1.05

Source: Central Transportation Planning Staff

Table 24
Year 2040 Bus Vehicle Crowding on Non-Radial Routes
Peak PM Hour of Each Route

Route	Start	End	Buses	Total Seats	Total Riders	Riders /Seat	Start	End	Buses	Total Seats	Total Riders	Riders /Seat			
1	Harvard	Dudley	9	351	428	1.22	Dudley	Harvard	9	351	404	1.15			
47	Central	Broadway	4	156	175	1.12	Broadway	Central	5	195	283	1.45			
66	Harvard	Dudley	7	273	346	1.27	Dudley	Harvard	7	273	342	1.25			
86	Sullivan	Reservoir	4	156	208	1.34	Reservoir	Sullivan	4	156	181	1.16			
CT1	Central	BU Medical	3	117	85	.73	BU Medical	Central	3	117	99	.85			
CT2	Sullivan	Ruggles	3	117	126	1.08	Ruggles	Sullivan	3	117	176	1.50			
CT3	Beth Israel	Andrew	6	234	150	.64	Andrew	Beth Israel	7	273	66	.24			
Total of Major Routes				36	1,404	1,519	1.08	Total of Major Routes				38	1,482	1,551	1.05

Source: Central Transportation Planning Staff

Silver Line SL1 service jumps from an unremarkable 1.25 riders per seat all the way to the overcrowded condition in 2040.

Comparing Tables 22 and 18 shows the increased crowding projected in 2040 during the PM peak period for radial services. Route 70, connecting Cambridge with communities to the west, becomes overcrowded, joining Routes 71 and 73 in this busy market. Route 57, also serving Watertown, becomes overburdened. South Boston and the Waterfront currently are served by the overburdened Routes 9 and SL1, both of which are expected to be overcrowded.

Ridership and crowding projections for the seven non-radial bus routes are presented in Tables 23 and 24 for the AM and PM peak periods, respectively. In the Base Year, four AM peak-period bus routes and two PM peak bus routes are considered overburdened. All six of these routes are predicted to be overcrowded by 2040. It is noteworthy that Route 66, predicted to increase from overburdened to overcrowded in the AM counterclockwise direction, will become overburdened in the AM clockwise direction as well as in both directions during the PM peak. Route 86 also will begin to experience overburdened conditions.

If ridership is expected to increase by 10 percent, increased peak-period crowding might be avoided simply by adding 10 percent more buses and drivers during the peak periods. This is appropriate for many, but not all, routes served by buses. If a heavily used route currently experiences bunching, increasing the frequency of service will not necessarily reduce bunching. Using larger buses on these routes can carry more passengers, reduce crowding, and often make bunching problems less severe. Higher-capacity articulated buses are expected to make up a larger portion of future vehicle purchases by the MBTA.

In the same manner as with rail rapid transit, bus vehicle capacity can be increased by reducing the number of seats in order to accommodate more standees. Reducing the number of seats also improves internal circulation within buses and allows improved, mandatory accommodation of wheelchairs, as well as baby strollers and personal shopping carts. The MBTA uses a policy standard of 1.4 passengers per seat, which is stricter than the 1.5-passenger standard respected in parts of the public transit industry. Current MBTA plans anticipate purchasing new standard-sized buses with fewer than 39 seats, and load policy standards will be revisited in conjunction with future procurements.

Bus vehicle crowding also may be lessened through route improvements. An example of this is the new Silver Line Gateway service that will operate between South Station and the Mystic shopping mall in Chelsea. This new service will add needed capacity in the Silver Line tunnel approaching South Station, where the Silver Line experiences the most crowding. However, the added commuters from

Chelsea will be using the tunnel in the inbound direction, where it has capacity to spare. Silver Line Gateway service also will reduce pressure on nearby bus Routes 111, 116, and 117, which are approaching the overburdened level.

5.6 Peak-Period Crowding on Commuter Rail

Developing Crowding Data

In recent decades, the commuter rail system serving Boston has seen the greatest growth in ridership of the several public transportation submodes. This growth, summarized in Table 10, was the result of several factors including system expansions, schedule improvements, and new equipment purchases. Some of these actions may be considered one-time improvements, and the growth shown in Table 10 cannot necessarily be extrapolated. However, the commuter rail system is configured to serve regional travel and gradually lengthening commutes.⁵

Trips on commuter rail tend to be longer than trips via rapid transit or buses, and are more concentrated during the AM and PM peak periods. Most trains operate from the most distant station on the line; the journey between this outermost point and one of the downtown stations usually requires at least an hour. Within real and inflexible operating constraints, train schedules are designed to bring riders to employment centers at preferred starting times, and leave these core stations soon after the close of business.

Typically, one inbound train in the AM peak and one outbound train in the PM peak will be the most crowded for each line. These specific trains have been identified, and this section focusses on their crowding levels. However, commuter rail ridership can be strong throughout the peak periods, and adding additional conveniently scheduled peak-period trains remains an ongoing challenge to system schedulers in Boston and other metropolitan areas, especially when track capacity needs to be shared with Amtrak or freight trains, as in Boston.

Because of the comparatively long travel times, commuter rail coaches are designed to maximize the number of seats. Some amount of standing is permissible, but ridership exceeding 1.1 times the number of seats is considered excessive by the MBTA. No trains in the Boston commuter rail system have ridership that is considered excessive by this criterion. Many standees are regularly observed, however, often because they wish to be near a door when the train arrives at their destination, or they were unable to find a seat to their liking.

⁵ *Exploring the 2011 Massachusetts Travel Survey: Focus on Journeys to Work*, Boston Region MPO, April 2014 http://bostonmpo.org/Drupal/exploring_2011_survey.

The key crowding metric used for this analysis is the necessity of using the unpopular middle seats, a standard feature on almost all MBTA commuter rail coaches. Coach seating is configured with two seats on one side of the aisle and three on the other, implying that about 20 percent of a train's seating capacity consists of the middle seat of the three-seat side. With the exception of parties traveling as a group, the middle seats are generally the last taken. When a train reaches this 80 percent threshold, boarding riders perceive a crowded condition, as they must now either take a middle seat or, as many do, just stand. While capacity that can safely be utilized is clearly available, the perception of crowding is important because commuter rail is sometimes considered a premium service.

Commuter Rail Crowding During the AM Peak Period

Crowding on the most heavily used inbound trains on each of the commuter rail lines is summarized in Table 25. The commuter rail system has several branches and endpoints; these have been grouped into 13 services in Table 25. They are arranged starting with the Rockport/Newburyport trains in the northeast, proceeding counterclockwise, and ending with the Greenbush trains in the southeast. The commuter rail system is shown graphically in Figure 23.

The first column shows the time that each trip is scheduled to arrive at its downtown station terminus. The first four services terminate at North Station and the other nine end at South Station. These popular arrival times cluster around 8:00 AM, with the earliest arrival being a Greenbush train at 7:36 and the latest being a Stoughton train at 8:32 AM.

The second column shows the number of seats that were available in the coaches that were assigned for use in these peak-period trains. The commuter rail operator assesses ridership demand and organizes the coach fleet into individual trains referred to as "consists." The largest consists have 1,356 seats, and are used on the AM peak trains from Worcester and Franklin.

Each AM peak-period commuter train accumulates passengers as it approaches North or South Stations. At some point, each train will reach its peak load for that trip; the number of passengers a train is carrying at this point appears in the next column. Morning peak-period trains are not necessarily carrying this peak load when they reach the final stop because on some lines a significant number of riders can alight at a close-in station convenient to local job centers.

Table 25
Crowding on Most Heavily Used Inbound Commuter Trains, AM Peak Period

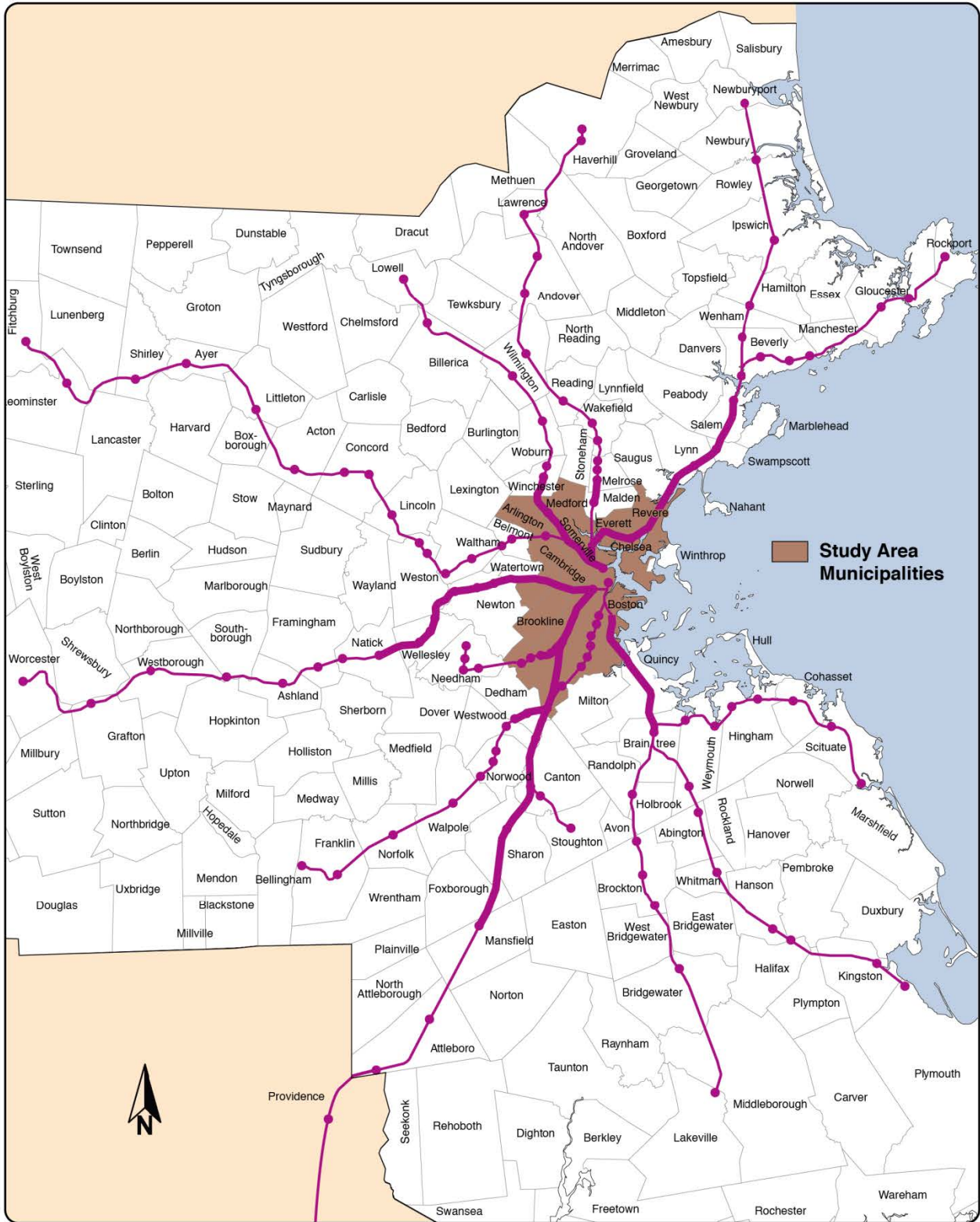
Inbound Service	Trip End Time	Trainset Seating Capacity	Number of Riders at Peak Load	Required Number of Middle Seats	Required Number of Standees	Minutes of Crowding
Rockport/Newburyport	7:58	798	854	159	56	27
Haverhill	8:00	570	469	13	--	3
Lowell	7:40	684	580	33	--	13
Fitchburg	8:22	750	582	--	--	--
Framingham/Worcester	8:23	1,356	1,171	86	--	20
Needham	8:14	706	678	113	--	15
Franklin	7:59	1,356	1,074	--	--	--
Providence	8:10	1,260	1,096	88	--	25
Stoughton	8:32	938	722	--	--	--
Fairmount	8:20	706	123	--	--	--
Middleborough	7:56	864	552	--	--	--
Plymouth/Kingston	8:12	996	833	36	--	21
Greenbush	7:36	864	596	--	--	--
Total Peak AM Trains	--	11,848	9,330	529	56	120

Source: Central Transportation Planning Staff.

The inbound train of the Rockport/Newburyport service has 798 seats, of which an estimated 159 are middle seats. Because the total riders on this train exceeds the total number of seats, all 159 middle seats are shown here as being “required” to accommodate the passengers. Even with this level of ridership, it is common for passengers to stand voluntarily, and for many of the 159 middle seats to go unused.

To accommodate all 854 riders, at least 56 riders would need to stand even if all 798 seats were occupied. The ratio of total riders to total seats is only 1.07, less than the 1.1 ratio considered the maximum allowable load for commuter rail service. This was the only train identified during either the AM or PM peak period for which the number of passengers exceeded the number of seats.

This train started in Rockport but ran express from Salem to Boston, the part of the trip where the peak load was observed. According to the schedule, the duration of travel under crowded conditions was 27 minutes. This section of the Rockport/Newburyport Line is highlighted in Figure 23, as are all parts of the commuter rail system that meet the definition of crowding during either the AM or the PM peak period.



BOSTON
REGION
MPO

FIGURE 23
Commuter Rail System and Locations with Crowding

*Core
Capacity
Constraints*

The most crowded train, from Haverhill, is crowded only for a three-minute stretch between Wyoming Hill and Malden Center. At Malden, enough passengers alight and go to a local destination or transfer to the Orange Line, making the use of middle seats on the commuter train no longer necessary to seat all passengers. Not only was the crowding brief, it was not particularly severe. With 570 total seats, 80 percent, or 456 riders can find seats without resorting to a middle seat. There were 469 total passengers, and the need to use 13 middle seats meets the crowding definition used here.

In addition to the express train from Salem, express trains from Natick on the Worcester Line and Mansfield on the Providence Line also were crowded for 20 and 25 minutes, respectively. The train from Lowell was crowded for the 13 minutes it required to travel from its last suburban station in West Medford to North Station. The Needham train was crowded for four stops from Bellevue to Back Bay station, but carried its peak load from Forest Hills station to Ruggles station, where many commuters alight.

Crowding on the Plymouth/Kingston Line presents an interesting situation. The need for middle seats extends from South Weymouth, through Braintree and as far as JFK/UMass. At JFK/UMass, enough people alight to make using the middle seats unnecessary. This service connects with and parallels the Red Line from Braintree north. Commuter rail passengers boarding at Braintree must pay a Zone 2 commuter rail fare, substantially more than the fare on the Red Line. The heavy use of this portion of the commuter rail system may be explained, in part, by the unacceptable level of Red Line crowding during the AM peak period, as shown in Figure 9.

It is important to note that other peak-period trains also may have similar crowded conditions as defined here, although they likely would have fewer riders at their peak loads than the trains discussed in this section. However, if they were operating with smaller equipment consists, then some level of crowding might be experienced.

Commuter Rail Crowding During the PM Peak Period

Table 26 identifies crowding conditions on outbound commuter rail trains. The table is organized in the same manner as Table 25, except that the times in the first column are the times that the trains leave North or South Station. The earliest departure shown is at 5:00 PM and the latest is at 5:40 PM.

Table 26
Crowding on Most Heavily Used Outbound Commuter Trains, PM Peak Period

Outbound Service	Trip Start Time	Trainset Seating Capacity	Riders at Peak Load	Required Middle Seats	Required Minutes of Standees	Minutes of Crowding
Rockport/Newburyport	5:15	798	658	20	--	20
Haverhill	5:35	684	481	--	--	--
Lowell	5:10	684	647	100	--	16
Fitchburg	5:20	750	558	--	--	--
Framingham/Worcester	5:00	1,356	1,023	--	--	--
Needham	5:20	703	698	136	--	18
Franklin	5:10	1,356	1,106	21	--	15
Providence	5:40	1,260	1,220	212	--	22
Stoughton	5:15	938	761	11	--	10
Fairmount	5:10	864	119	--	--	--
Middleborough	5:12	864	585	--	--	--
Plymouth/Kingston	5:38	996	621	--	--	--
Greenbush	5:20	864	546	--	--	--
Total Peak PM Trains		12,117	9,023	499	none	114

Source: Central Transportation Planning Staff.

Six commuter rail services experience crowding during the PM peak period. Four services that are crowded in the inbound direction also are crowded in the outbound direction over much of the same track: Newburyport trains from North Station to Lynn, Lowell trains from North Station to Wedgemere, Needham trains from Back Bay to Bellevue, and Providence trains from Back Bay to Sharon. The duration of crowded conditions for these four services is 80 minutes in the inbound direction and 76 minutes in the outbound direction.

A small number of middle seats are required for the peak outbound Franklin and Stoughton trains. Both of these trains reach a slightly crowded condition when they pick up passengers at Ruggles and continue on a rail line that they share with Providence trains. The Stoughton train is crowded for only 10 minutes until it reaches Hyde Park, still on the main line. The Franklin train is crowded for 15 minutes until it reaches Dedham Corporate Center, the second station after switching from the main line to the Franklin branch.

Accommodating Increased Commuter Rail Ridership

The commuter rail system is well positioned geographically to serve the anticipated growth in regional travel demand. Comparing Figures 2 and 23 shows how the regional patterns of residential and commercial growth mirror the regional extent of the commuter rail system. Developments including both housing and employment are envisioned in the 2040 No-Build scenario in the suburbs as well in study-area locations like the South Boston Waterfront, which were not included in the 2040 Build scenario. The Build scenario envisions 72

additional large-impact developments (see Figure 4) in the study area, which also includes both housing and employment.

Including both housing and jobs in a concentrated development area encourages walking and bike riding as commuting modes. Building employment centers close to suburban commuter rail stations enables reverse commuting, which is the pattern where the commuter rail system has capacity to spare. However, it should be anticipated that demographic, economic, and development trends will add a significant amount of peak-period radial commuting and that the commuter rail system should be expected to accommodate a significant share of this radial commuting growth.

The analysis in this section suggests that crowding on the commuter rail system is not severe at present. Only on one peak-period train is it necessary for some riders to stand. On about half of the most heavily used peak-period trains is there some level of perceived crowding because of the need to use a middle seat, or to stand to avoid doing so. Any perceived crowding will, in most cases, be less severe on the less heavily used peak period trains.

Broad-based growth in commuter rail ridership will result in involuntary standing on some lines. For instance, the 5:10 PM Lowell train is only 37 new passengers away from filling its 684 seats. The gradual introduction of bi-level coaches to trains operating out of North Station as older single-level coaches are retired will allow these trains to manage crowding well into the future.

Accommodating growth without crowding will be more difficult for services that already use large equipment consists with eight coaches, seven or eight of which are bi-level. For these services, it would be necessary to add trains, optimize schedules, or both. In these cases, adding useful capacity may involve diverse institutional, operational, infrastructure, and safety issues.

The Commonwealth's acquisition of the Worcester Line, and relocation of the very active CSX intermodal operations from Allston to Worcester, have made some service and capacity improvements possible. However, the Boston Landing station, now under construction, will both add ridership and require operational adjustments. Ongoing efforts to improve operations and capacity on this line should be expected.

The Providence Line is shared by Needham, Franklin, and Stoughton commuter trains as well as Amtrak's trains to New York and Washington, DC. The large, heavily used commuter rail consists serving Franklin and Providence need to use this busy corridor that has virtually no capacity to spare given the applicable safety standards. One proposal is to add a second commuter rail platform at

Ruggles station, which would simplify the safe movement of peak-period trains serving this increasingly popular commuting destination.

The three Old Colony services, Middleborough, Plymouth/Kingston, and Greenbush, do not yet experience severe crowding and, in the near future, could deal with any capacity issues by operating larger consists. The problem with these services is the current need to operate on a part of the commuter rail system that is mostly single-tracked. This presents two general problems. First, seemingly minor events, such as a particularly large crowd loading at a station could create schedule problems that are difficult to recover from in a single-tracked system. Second, it is more difficult to design schedules with attractive departure and arrival times if they need to allow time windows for trains going in the opposite direction to pass at some point.

Designing schedules that are convenient for commuters is a problem on any fully utilized commuter rail line, including the Worcester Line and the four services sharing the Providence Line. The effort required to add a platform at Ruggles station might not necessarily allow for an added Providence train. However, it might allow a train that currently operates with capacity to spare to be operated safely in a more popular time slot, thereby attracting more riders. Extending some of the double-tracked sections of the Old Colony Line not only would improve reliability, but also could allow for designing more attractive schedules.

Chapter 6—Transportation Mitigation Policies

6.1 Broad-Based Travel Growth and Individual Developments

Broad-based demographic and economic growth and major large-impact developments in the study area and surrounding region will add substantial travel demand across all modes. Financing any additional capacity required to accommodate this growth is a topic of ongoing policy concern.

The challenge today is that important parts of the regional transportation system are utilized at levels close to their maximum capacity. Increased travel demand at these locations, whether caused by nearby developments or regional travel growth can require significant capital investment. This problem is exacerbated by accelerating repair costs for those parts of the system that are nearing the end of their designed lifespan.

New workers, businesses, and property owners will pay to use publicly provided transportation capacity directly through gasoline taxes, roadway tolls, and public transportation fares. The projected new transportation consumers also will provide financial support indirectly through income and property taxes allocated to transportation and other public services via the political process, and through the same funding mechanisms as transportation users do now.

Although new users would use the entire regional transportation system in the same manner as existing users, local and state regulators recognize some level of special responsibility in cases where an increase in demand associated with a particular development or business expansion is sufficiently large that the quality of existing transportation at that location would be materially reduced. Policies and programs where the development or expanding business is expected to help accommodate, to some degree, the added transportation demand are referred to generally as mitigation.

Mitigation arrangements usually focus on impacts near where the new travel demand is generated. New travel demand would affect the entire region, albeit at lesser levels the further away it is from where new demand is generated. Parts of the transportation system that are reaching capacity can be pushed to their limits by the combined impacts of numerous new or expanding trip generators scattered throughout the region. The user fees and region-wide taxes mentioned above that are common to both existing and prospective transportation users are expected to contribute to the expansion of regional capacity and subsidized services. However, it is easier to both justify and effectively plan mitigation at the source of the new demand. Moreover, municipalities can only arrange for mitigation within their municipal boundaries.

The next section of this chapter describes various types of mitigation policies and programs, which are organized into three general groups: traffic systems management (TSM), transportation demand management (TDM), and transit mitigation. These groupings do not have strict boundaries and mitigation efforts can have a range of effects. A review of the mitigation strategies and techniques that are being utilized by the nine study-area municipalities and state and regional operating agencies is included in Appendix I. This chapter concludes with a discussion of possible changes to fee and tax structures related to new developments.

6.2 Mitigation Strategies and Techniques

Traffic Systems Management

The longest-standing mitigation practice involves improving the street system near a new development or business expansion. While the nearby roadway system and site access may be in technical compliance with applicable traffic engineering standards, introducing a major new trip generator provides an opportunity and potential to make more substantial roadway improvements, optimize the street system for the new development, and perhaps make other transportation improvements not directly related to the new development.

Barring a sustained economic downturn, a new development will result in some level of increased traffic because of increased activity at the site. A successful mitigation program will accommodate this traffic and minimize speeding, queuing, or diverting traffic into nearby neighborhoods. Optimizing the locations of bus stops is another aspect of TSM efforts and can make the transit mode more attractive. In addition, improving the pedestrian and bicycle travel environments will encourage use of non-motorized modes. Possible TSM actions include:

- Adding or removing streets
- Adding or removing travel lanes
- Adding or redesigning turning lanes
- Re-striping roadways
- Modifying site access: adding or changing curb cuts
- Re-timing or modernizing traffic signals
- Utilizing intelligent transportation systems (ITS), such as monitoring equipment
- Improving truck and service access; scheduling, and recommending truck routes
- Re-locating or consolidating bus stops
- Installing bicycle lanes and paths
- Improving sidewalk and streetscapes
- Mitigating construction impacts
- Developing longer-range TSM plans

Transportation Demand Management

As its name implies, transportation demand-management policies and programs are designed to change the transportation demand associated with a major trip generator. This can involve reducing the number or lengths of trips, encouraging use of certain modes, changing the timing of trips, and in some instances encouraging trips to specific preferred endpoints.

The most common TDM goal is to reduce the amount of auto use at a location for a given level of activity. Large, successful developments and businesses require access by large numbers of people using all modes. TDM seeks to reduce both peak-period and daily auto use without jeopardizing the economic viability of a location. While use of transit generally is encouraged, sometimes strategies to move transit use away from crowded peak periods to less-crowded times are sometimes used.

There is a wide variety of TDM tools representing a mix of facility improvements, specialized travel services, work options, travel incentives, pricing strategies, and providing information. These tools are discussed below, in five groups generally by mode.

- 1) Actions that reduce the need to travel at all, or the need to travel during peak periods, including:
 - Policies allowing working at home or telecommuting
 - Flexible workday schedules, including four-day week options
 - On-site childcare
- 2) Actions related to parking (the supply, cost, and management of parking is arguably the most powerful TDM tool available), including:
 - Adding fewer parking spaces than allowed in a new development
 - Charging employees market-rate parking fees
 - Compensating non-drivers if parking is free
 - Providing charging stations and preferred spaces for zero-emissions vehicles

Some TDM programs seek to encourage the use of public transportation. Meaningfully improving the public transit system may not be expected of the businesses or institutions applying TDM tools.

- 3) Actions at a location that could increase transit use, including:
 - Subsidizing purchase of transit passes
 - Selling Charlie Cards on site

- Providing websites and maps that are focused on transit options at the location
- Offering transit-orientation packets for new employees or residents

Another group of TDM activities provide or promote services configured specifically for the needs of an employer or development. Sometimes the term “paratransit” is used for services where medium-sized vehicles are shared efficiently to offer high-quality mobility services.

4) Facilities that specifically benefit the needs of an employer or development, including:

- Van service for multiple residences with the same work location
- Employer-provided shuttle service to transit
- Remote parking with shuttle service
- Free and convenient parking for registered carpools
- Promoting carpooling, such as MassRIDES
- Transportation management association (TMA) participation
- On-site transportation coordinator

The last TDM group includes actions aimed at encouraging the non-motorized modes, walking and bicycling.

5) Conditions that can encourage non-motorized modes, including:

- Ample secure bicycle storage
- Locker rooms with showers
- Sponsorship of stations for bicycle-sharing services such as Hubway
- Incentives for bicycling and walking

Developers or their business, or institutional tenants would be able to implement all of the TDM measures mentioned in this section. Some of these TDM actions also could be realized on a much larger scale via government action, and could be expected to impact transportation demand over a much larger part of the travel market than just individual development locations. City- or region-wide change in parking costs is an example of this. Congestion pricing within an urban core also could have a major impact on travel demand. This type of policy clearly would need to be executed on a governmental rather than individual-project basis.

Transit Mitigation

The third family of mitigation strategies is transit mitigation. This is a wide-ranging topic, which is presented here in two parts. In this subsection, we discuss transit-mitigation actions that are roughly analogous to the TSM and TDM strategies

described above. These include mitigation options that can be negotiated with developers within the framework of the current laws and regulations that enable and limit TSM and TDM strategies in Massachusetts. In the next section, we discuss options for changing fee and tax structures relating to development impacts.

As with TSM and TDM, transit mitigation can be ambitious in scope and expense, but it focuses on improving transit services near a development or business expansion. While transit mitigation may be structured as a regulatory demand upon a developer, it may be framed as directly beneficial to the development, lending a strong legal, political, and economic basis to such programs. Transit mitigation actions of this scale include:

- Subsidizing or facilitating added MBTA bus, train or boat service
- Investing in station facilities including:
 - Expanded or lengthened platforms
 - Walkways to stations
 - Accessibility features
 - New station or boat dock
- Paying for maintenance of station facilities
- Incorporating transit features within a development, such as:
 - Information kiosks
 - Fare vending machines
 - Dedicated bus lanes

Given the cost of transit infrastructure and the expenses of daily transit operations, the mitigation expected of a typical development will have only a limited impact on the system as a whole even if it is effective in the project area. However, several especially large projects have enabled some major improvements with system-wide benefits. Four of these large-scale mitigation efforts are described briefly here, and are discussed more fully in Appendix I.

Kendall/MIT Station

As part of the agreement to build two buildings in the Cambridge Center complex, Boston Properties funded major improvements to the Kendall/MIT Red Line station. The most important improvement was lengthening the station platforms to allow service with six-car trains. Station interiors were upgraded and entrances relocated. Boston Properties also agreed to operate and maintain Nowiszewski Plaza in front of the station entrance on Main Street.

Assembly Station

As part of the agreement to build the Assembly Row complex adjacent to the existing Assembly Square mall in east Somerville, the developer, Federal Realty Investment Trust, paid a significant portion of the costs of building the recently completed Assembly Orange Line station. While this major improvement facilitates the use of transit at this rapidly developing area, it actually exacerbates the Orange Line crowding problem.

New Balance

As athletic gear-maker, New Balance, develops its new world headquarters in a formerly industrial section of Allston, it is constructing a new station on the Worcester commuter rail line. As part of its mitigation agreement, New Balance also committed to covering station maintenance costs for several years in exchange for two guaranteed peak-period trains in each direction stopping at the new station on weekdays.

Wynn Boston Harbor

The Wynn casino project in Everett is the largest project to date in which the MBTA has actively engaged in discussions about transit impacts based on new trips generated to the site. Potential mitigation measures are not yet finalized, but would focus on better utilizing the existing transit infrastructure. Measures that have been suggested include operational subsidies for expanded Orange Line or bus service, and roadway changes to improve bus access to Sullivan Square Station.

6.3 Modifying Tax and Fee Structures

Expanded Funding Policies in Other States

Requirements for developers and expanding businesses to support public transportation financially in Massachusetts are generally limited to the broad-based taxes and mitigation arrangements discussed in the previous section. Other financing mechanisms have been enacted and applied in other states and these efforts are briefly described in this section.

One approach, referred to broadly as “value capture,” is more often used to finance service expansion than reconstruction. Where public transportation infrastructure investments increase adjacent land values or increase the potential for development, communities can use some of the increase in property values, property sales, and income taxes to help finance the capital, debt service, or operating costs of that infrastructure. Strategies for capturing the increase as a result of the local infrastructure are varied, and include joint-development agreements, special-assessment districts, and tax-increment financing (TIF),

which captures the growth in property tax revenue resulting from improved transit service, and uses these funds for debt service or other public investments.

The TIF approach also has been used to finance other public enhancements such as open-space improvements, site redevelopment, and historic preservation. Seattle property owners agreed to help fund half of the cost of the South Lake Union streetcar expansion through a special assessment within the Local Improvement District. Construction of Phases I and II of the Washington Metropolitan Area Transit Authority (Washington, DC) Metro Silver Line was funded in part by special assessments on nonresidential property around future transit stations. Denver used a 30-year TIF district around the Union Station rail hub to support station rehabilitation and transit expansion, where property taxes generated from neighborhood development in the 20 acres surrounding the station are devoted to debt service on federal loans.

Another example of transit mitigation financing is impact fees on new developments, or significant renovations in an area with transit service. The availability of transit service to these projects implies that they could meaningfully increase transit ridership, the costs of which would be recovered only partially through user charges. Impact fees support a transit-only improvement fund that can be used to pay for capital expenses or, less commonly, operating expenses of the transit service. Often, the agency receiving these fees can use the funds anywhere in the system.

San Francisco enacted a Transit Impact Development Fee (TIDF) in 1981 that is charged to nonresidential developments of more than 3,000 gross square feet in order to help fund transit service that can offset the traffic impacts created by developments, with no time limit on the use of collected fees. The TIDF covers only a small portion of operating and capital costs of the San Francisco Municipal Transportation Agency, the “Muni,” which operates the city’s bus and streetcar network. Originally implemented in the downtown area to boost peak capacity for office commuters, TIDF was expanded in 2004 to cover the entire city.⁶ In July 2015, legislation was introduced to the city council to replace TIDF with a new Transportation Sustainability Fee that includes residential developments larger than 20 units under the fee structure.⁷ This fee will pay for maintenance and expansion of the Muni fleet, upgrading Bay Area Rapid Transit and Caltrain rolling stock, and improving bike lanes and intersections.

⁶ http://www.sf-planning.org/ftp/files/legislative_changes/new_code_summaries/120523_TIDF_Transportation_Impact_Development_Fee_Update.pdf

⁷ http://www.sf-planning.org/ftp/files/plans-and-programs/emerging_issues/tsp/tsp_TSF_Fact_Sheet_072115.pdf

Similar to San Francisco, Huntington Park, California, in Los Angeles County, requires a Transit Mitigation Fee as a condition of project approval that covers the costs of facilities required to be constructed to service the development.⁸ The Portland, Oregon Transportation System Development Charge applies, in varying rates, to new developments and property-use changes and is used to finance only qualified projects in the city's Capital Improvement Plan that increase the capacity of the transportation system.

Seattle offers a slightly different approach to transit mitigation. As Washington's Growth Management Act restricts the use of impact fee funds to roadway improvements only, Seattle used the State Environmental Policy Act (SEPA) process to create a voluntary multimodal program. The city asks developers to fund planned multimodal transportation facilities through development impact mitigation payments. In response, developers then are relieved of traditional impact fees required as part of an environmental review conducted through SEPA. Improvements do not need to reduce or eliminate existing deficiencies, only account for the development's impacts.⁹ Funds received through transportation mitigation payments are earmarked specifically for projects on a list predetermined by the city and negotiated with the developer. The funds are kept in a special reserve account; if not used within five years for the specified projects, they will be refunded with interest, unless the delay can be attributed to the developer.¹⁰

Expanded Funding Policies in Massachusetts

The limited Massachusetts transit mitigation actions described in the previous section can meaningfully improve access to transit and the user experience. The overall condition of the transit system, financial requirements of its operations, and envisioned system expansion can only be marginally addressed through transit mitigation as practiced today in Massachusetts.

The Governor's Special Panel to Review the MBTA issued a report in April 2015, which commented on virtually every aspect of MBTA finance and operations. One finding concerned the modal equity of mitigation as currently practiced in Massachusetts:

“Having new development projects located near MBTA transit stations financially support MBTA service [could be included] as part of the developer

⁸ http://qcode.us/codes/huntingtonpark/?view=desktop&topic=9-3-14-9_3_1406

⁹ <http://www.westernite.org/Sections/washington/newsletters/Samdahl%20multimodal%20impact%20fees.pdf>

¹⁰ <http://www.seattle.gov/DPD/publications/CAM/cam243.pdf>

mitigation process. While mitigation payments for roadway improvements are a routine and common practice in Massachusetts, the equivalent support for MBTA operations almost never occurs. Mitigation payments for MBTA improvements would become an established practice.”¹¹

The Governor’s Panel report also mentioned funding mechanisms that would require legislation. It suggests “exploring the use of District Improvement Financing (DIF) for municipalities, and pledging a portion of incremental property tax collections to cover a portion of the costs for major MBTA capital projects, especially debt payments over time.”¹²

In practice, DIFs would function as TIF districts. DIFs can fund public infrastructure ranging from waste water facilities, transit stations, seawalls, street lights, playgrounds, brownfield mitigation, and parking garages. For those potentially placed around MBTA stations, station enhancement and system upgrades are all eligible because they are owned by a public entity.

Another funding mechanism that would require legislation is impact fees, a practice now legal in a number of other states. The need for legislation was established by a court case in 2000 concerning a school-impact fee levied on developers in the town of Franklin. The Massachusetts appeals court found Franklin’s fee to be an impermissible tax rather than a municipal fee valid under its Home Rule Amendment. The decision limits individual municipalities’ ability to collect funds for public improvements that are necessary as a result of development.

Enabling legislation for value-capture and impact fees would pose a number of equity issues. Congestion is caused by the combined burdens of both existing users and new users. The expectation that a higher level of financial support would be derived from new users than from existing users would need to be vetted in the political process. Implementation of value-capture would require resolution of similar issues, such as the fairness of defining project beneficiaries by drawing a boundary.

Without legislation that enables value-capture or impact fees, municipal officials and operating authorities must use currently available mitigation arrangements that focus on the location of individual developments and business expansions. If

¹¹ Governor’s Special Panel to Review the MBTA. *Back on Track: An Action Plan to Transform the MBTA*. (April 8, 2015). <http://www.mass.gov/governor/docs/news/mbta-panel-report-04-08-2015.pdf>.

¹² Governor’s Special Panel to Review the MBTA. *Back on Track: An Action Plan to Transform the MBTA*. (April 8, 2015). <http://www.mass.gov/governor/docs/news/mbta-panel-report-04-08-2015.pdf>.

the congested bottleneck is not near the development, then currently there is no mechanism to apply the mitigation funds to the bottleneck. Even if a congested bottleneck happens to be at a new development, the cost of significantly expanding capacity may far exceed any potential mitigation payment.

Chapter 7—Summary and Conclusions

7.1 Crowding and Congestion

A recurring theme in this study is that both the generation and impacts of increased travel demand are regional. If new travel demand is generated at one location at a sufficient scale, the impacts of this incremental demand can be estimated and appropriate responses may be available to accommodate the added demand at that location. As the added travelers move farther from a new development, they add their travel to the regional travel congestion regardless of the mode, or modes, they utilize.

Because the available data and operational characteristics vary significantly between the various transportation modes and subsystems, we have analyzed each part of the transportation system individually. The Base Year and year 2040 capacity and travel demand were analyzed together for each subsystem, and where possible, travel demand that could be directly attributed to the selected large-impact projects also was analyzed. Some of the findings of these analyses include:

- **Roadways**

In the Base Year, about 25 percent of major study-area roadways are congested during the AM peak period, and about 39 percent are congested during the PM peak. These percentages are projected to increase to 34 and 51 percent, respectively, by 2040. About 24 percent of this increase may be attributed to the 72 selected large-impact projects, but these impacts are distributed widely across the study area.

- **Red Line**

The Red Line has the highest capacity of the four rapid transit lines, and experiences meaningful crowding today only on commutes from Quincy and Braintree. This is largely a consequence of this branch being served by only half of the Red Line trains. Future growth, especially from the selected large-impact projects, will exacerbate crowding in this commuting market.

- **Orange Line**

The Orange Line has meaningful crowding today on commutes from the north, but no crowding at all on commutes from the south. Congestion on these commutes will increase by 2040, and the selected large-impact projects will result in severe crowding. In 2040, congestion on commutes from the south will still be negligible.

- **Green Line**

Crowding on the Green Line depends to a large degree on how many of its four branches operate at any particular point in the system. Crowding in the Base Year is almost entirely during the PM peak period, eastbound on the E branch at Prudential, and westbound from Park Street to Kenmore. Crowding in 2040 is expected to become severe throughout the Green Line tunnel system primarily as a result of the 72 selected large-impact projects.

- **Blue Line**

There is virtually no crowding on the Blue Line today under normal circumstances. In 2040, a small amount of crowding is expected crossing from Maverick to downtown Boston in the AM and returning in the PM. None of this crowding will be a result of the 72 large-impact projects.

- **Bus-Vehicle Services**

A sufficient number of bus trips are operated in the study area to accommodate travel demand with very little crowding. The year-2040 ridership was estimated only for the system as a whole, and the impact of just the large-impact projects has not been calculated. Ridership growth may be accommodated with more trips or larger vehicles.

- **Commuter Rail**

Crowding is not a widespread problem in the commuter rail system. Riders view commuter rail as a premium service, and on a few trains, some riders need to either stand or use the less-desirable “middle seats.” Any crowding, real or perceived, may last as long as 20 or 25 minutes because of station spacing. Standardizing on larger, bi-level coaches will allow future ridership growth.

7.2 Mitigation

Three types of mitigation—traffic systems management, transportation demand management, and transit mitigation—represent distinct approaches to the problem of how best to accommodate a large increase in trip generation in an already congested area. These three approaches include a wide assortment of planning and program options that can be implemented successfully at a range of price points. With close collaboration between developers, planners, and permitting authorities, mitigation programs can meaningfully reduce or modify transportation impacts. However, any new development or increase in business activity will add some amount of regional travel demand.

The most ambitious mitigation agreements often require a significant expenditure, such as constructing or re-constructing a rail transit station. The recent construction of the Assembly Orange Line station by the Assembly Row developers is an example of a significant improvement to the transportation system financed through a mitigation agreement with a developer.

The construction of a new station near a new development conforms to current mitigation practices in Massachusetts. The new station makes transit an attractive mode for users of the new development, which is the express purpose of the new station. However, these new users travel throughout the transit system, contributing to congestion across the entire network.

With new legislation, funding mechanisms such as value-capture or impact fees could allow funds derived from a new development to be used in parts of the transit system not directly related to the development itself. It would be possible for investments funded through mitigation to be focused on an important pinchpoint rather than simply improving the area of the funding development. Even with this flexibility, the funds derived from a single developer would be insufficient to expand the entire system's capacity meaningfully. Ultimately, user fees and broad-based revenue sources will be required to add capacity to the region's transportation systems.



CORE CAPACITY CONSTRAINTS

APPENDICES



Core Capacity Constraints: Appendices

Accommodating Growth on Greater Boston's Congested Roads and Crowded Transit System

Project Manager

Bruce Kaplan

Project Principal

Scott Peterson

Report Author

William Kuttner

Data Analysts

Brynn Leopold

Drashti Joshi

Ian Harrington

Tom Humphrey

Graphics

Ken Dumas

Jane Gillis

Cover Design

Kate Parker-O'Toole

The preparation of this document was supported by the Federal Highway Administration through MHD 3C PL contracts #32075 and #33101.

Central Transportation Planning Staff
Directed by the Boston Region Metropolitan Planning Organization. The MPO is composed of state and regional agencies and authorities, and local governments.

August 2016

Table of Contents

Appendix A Land Use and Development

Appendix B Travel Demand Forecasting

Appendix C Roadway Congestion

Appendix D Rapid Transit Service Frequencies

Appendix E Base-Year Passengers

Appendix F Passengers per Vehicle: Base Year

Appendix G Passengers per Vehicle: Year 2040 No-Build Scenario

Appendix H Passengers per Vehicle: Year 2040 Build Scenario

Appendix I Transportation Mitigation Practices

Appendix A

Land Use and Development

Support data related to demographic and development trends presented in Chapter 2 have been grouped together in Appendix A. These include:

- Municipal and regional land areas used to calculate densities and density trends (Table A-1)
- Locations of the 20 sample TAZs shown graphically (Figure A-1)
- Brief descriptions of the 72 large-impact projects in the 20 sample TAZs (Table A-2). The TAZs are listed in the same order as in Table 5 of the report: from north-most to south-most.
- Brief descriptions of nine projected large developments which are not located in the 20 sample TAZs (Table A-3). The TAZ numbers of these projects are noted and the TAZs are also shown in Figure A-1.

Table A-1
Study Area and Boston MPO Region Land Areas
Square Miles

Boston	48.7
Cambridge	6.5
Somerville	4.1
Brookline	6.8
Medford	8.0
Revere	5.8
Arlington	5.2
Everett	3.4
Chelsea	2.2
Study Area	90.7
Rest of MPO	1,313.7
Entire MPO	1,404.4

Source: Central Transportation Planning Staff

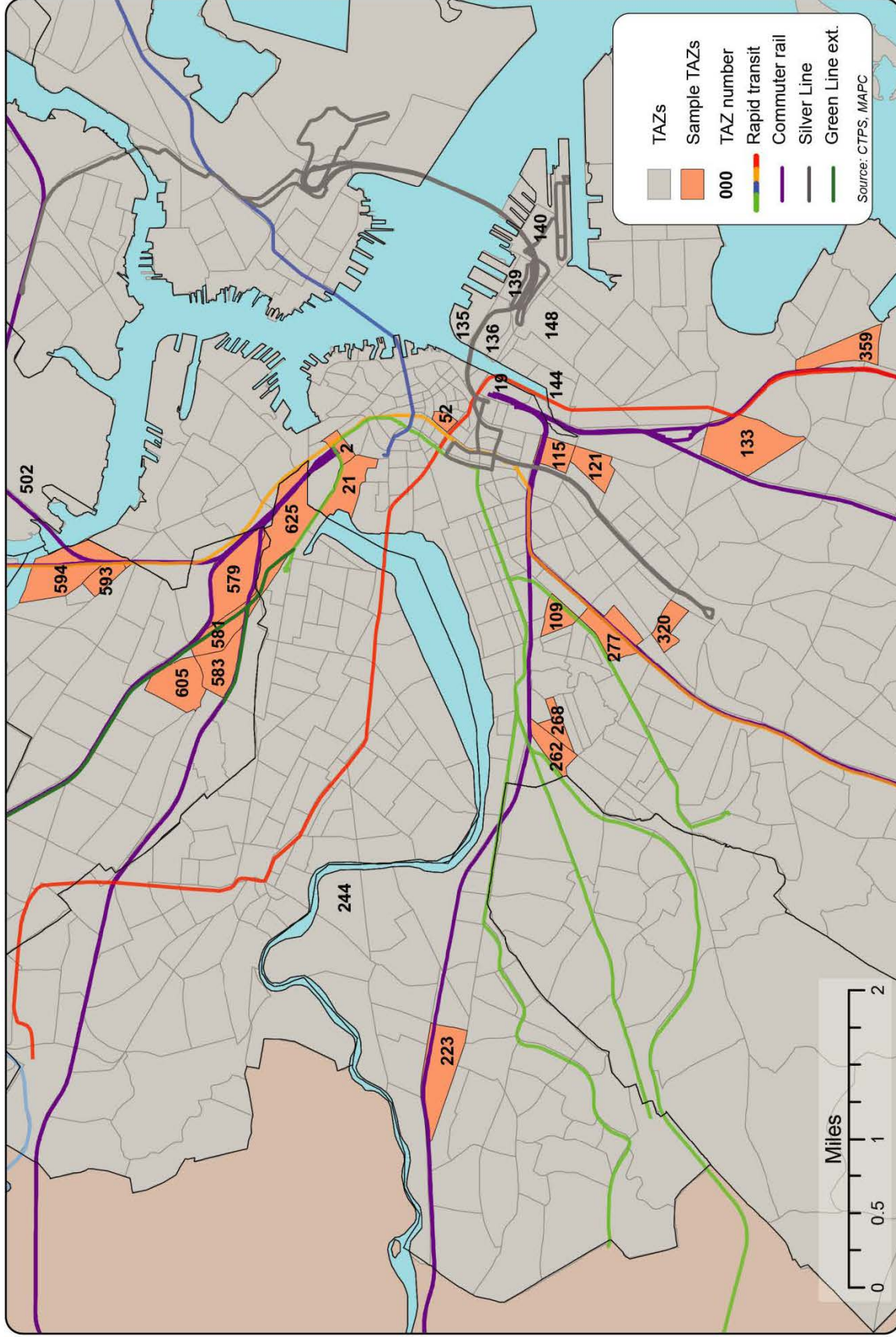


FIGURE A-1
Traffic Analysis Zones (TAZs)
with Large-Impact Developments

**BOSTON
 REGION
 MPO**

**Core
 Capacity
 Constraints**

Table A-2
Large Impact Projects in the Sample TAZs
Somerville and Cambridge

TAZ	City	Development	Completion Year	Total Housing Units	Expected Residents	Commercial Square Feet	Expected Jobs
594	Somerville	Assembly Row: Block 11 (Phase 2)	2027	0	0	330,000	1,184
	Somerville	Assembly Row: Block 5	2018	285	658	125,560	314
	Somerville	Assembly Row: Block 6	2027	447	1,033	40,000	100
	Somerville	Assembly Row: Block 7	2027	233	538	649,393	2,471
	Somerville	Assembly Row: Block 8	2027	0	0	680,971	2,632
	Somerville	Assembly Row: Block 3 (Future)	2027	547	1,264	11,654	29
	Somerville	Assembly Row: Block 11 (Phase 1)	2015	0	0	874,297	3,340
	Somerville	Assembly Row: Block 9	2027	0	0	490,179	1,961
	Somerville	Assembly Row: Rest of Permitted Development	2027	215	497	389,928	1,413
593	Somerville	Assembly Square - 2nd Urban Renewal District	2037	2,000	4,620	3,000,000	9,636
605	Somerville	25 Hamlet	2015	2	5	0	0
	Somerville	Union Square Revitalization: D-5	2027	208	480	573,581	2,010
	Somerville	Union Square Revitalization: D-7	2027	18	42	49,570	174
583	Somerville	Union Square Revitalization: D-2	2027	176	407	484,460	1,698
	Somerville	Union Square Revitalization: D-1	2027	105	243	290,243	1,017
	Somerville	Union Square Revitalization: Rest of Development*	2027	96	222	2,219,749	7,780
581	Somerville	Brickbottom Redevelopment	2027	750	1,733	1,600,000	4,711
579	Somerville	Inner Belt Redevelopment	2035	1,000	2,310	2,800,000	8,245
625	Cambridge	20 Child St. / North Point Bldg N	2015	341	788	2,400	6
	Cambridge	Water St., #22 (Mac-Grey)	2015	392	906	0	0
	Cambridge	East Street Phase 2, #1-25 (Smith)	2017	341	788	2,400	6
	Cambridge	219 Monsignor O'Brien Highway	2015	0	0	0	107
	Cambridge	EF Proposed Building	2025	0	0	381,000	1,182
	Cambridge	North Point Master Plan - Remainder (Guilford/S&S)	2032	1,796	4,149	1,771,030	6,606

Table A-2 (cont.)
Large Impact Projects in the Sample TAZs
Boston

TAZ	City	Development	Completion Year	Total Housing Units	Expected Residents	Commercial Square Feet	Expected Jobs
21	Boston	Garden Garage Site Redevelopment	2015	500	1,155	500,000	1,250
2	Boston	Nashua St Residences at the Fleet Center	2020	503	1,162	0	0
	Boston	The Boston Garden	2018	497	1,148	900,000	3,394
223	Boston	Brighton Landing South Parking project	2027	0	0	0	0
	Boston	Boston Landing	2027	0	0	1,315,000	4,684
	Boston	37 North Beacon Street	2027	180	416	0	0
	Boston	Lowe's Brighton	2025	0	0	146,000	365
	Boston	217 Market Street (Market Street Crossing)	2025	116	268	26,525	66
	Boston	District 9 at 61 North Beacon Street	2020	76	176	0	0
	Boston	New Brighton Landing	2015	0	0	1,210,136	4,811
52	Boston	One Franklin/Filene's Redevelopment	2020	140	323	756,700	2,974
	Boston	Millennium Tower and Burnham Building	2016	0	0	370,000	1,203
262	Boston	Parcel 7 Air Rights	2027	330	762	0	0
	Boston	Landmark Center North Addition	2027	550	1,271	0	0
	Boston	Turnpike Air Rights Parcels 7 & 8	2020	282	651	447,000	1,636
	Boston	121 Brookline Avenue	2020	0	0	117,000	459
	Boston	Landmark Center Redevelopment	2018	550	1,271	200,000	523
268	Boston	1271 Boylston Street	2027	184	425	4,000	184
	Boston	Fenway Point	2027	320	739	0	0
	Boston	1282 Boylston	2015	350	809	10,000	1
	Boston	Fenway Triangle Mixed Use Project	2015	300	693	450,000	1,530
109	Boston	Belvidere Street	2030	80	185	10,000	25
	Boston	Belvidere/Dalton West	2027	225	520	0	0
	Boston	Belvidere-Dalton Project	2027	500	1,155	0	0
	Boston	Christian Science Plaza Revitalization Project	2020	0	0	952,000	2,356

Table A-2 (cont.)
Large Impact Projects in the Sample TAZs
Boston (cont.)

TAZ	City	Development	Completion Year	Total Housing Units	Expected Residents	Commercial Square Feet	Expected Jobs
115	Boston	Harrison/Albany Master Plan - NY Streets - East	2035	467	1,079	590,367	2,610
	Boston	Harrison/Albany Master Plan - NY Streets - Central	2035	358	827	420,391	1,588
	Boston	Hamilton Towne Gate	2030	97	224	11,106	28
	Boston	345 Harrison Street	2027	560	1,294	0	0
	Boston	1000 Washington Street	2015	0	0	100,000	400
	Boston	Ink Block- 300 Harrison Avenue	2015	471	1,088	65,000	163
121	Boston	Harrison/Albany Master Plan - Back Streets	2035	0	0	2,427,338	9,709
	Boston	Harrison/Albany Master Plan - SOWA	2035	627	1,448	1,332,911	5,214
	Boston	600 Harrison Avenue	2027	160	370	0	0
277	Boston	316-320 Huntington Avenue	2030	450	1,040	0	0
	Boston	GrandMarc Residence Hall at Northeastern University- 316 Huntington Ave	2027	700	1,617	0	0
	Boston	New England Conservatory Residence Hall- 0 St. Botolph and Gainsborough	2027	252	582	0	0
	Boston	Northeastern University - Interdisciplinary Science & Engineering Ctr	2018	0	0	197,000	276
	Boston	New England Conservatory- 286 Huntington Avenue	2017	0	0	65,000	91
320	Boston	Cescent Parcel Roxbury	2030	0	0	220,000	820
	Boston	Tremont Crossing	2027	300	693	1,000,000	2,700
133	Boston	South Bay Planning Study (MTA Parcels)	2035	1,500	3,465	2,500,000	9,250
	Boston	Target South Bay Expansion	2020	0	0	21,700	54
359	Boston	Columbia Point Master Plan - Synergy Site	2035	500	1,155	438,200	1,621
	Boston	Columbia Point Master Plan - MBTA Site	2035	0	0	257,500	1,019
	Boston	Columbia Point Master Plan - BG Site	2035	430	993	0	0
	Boston	25 Morrissey Boulevard	2027	278	642	0	0
	Boston	Herb Chambers at 75 Morrissey Blvd	2027	0	0	27,706	69

TAZ = transportation analysis zone.

SoWa = South of Washington Street.

Source: MAPC regional development database.

Table A-3
Other Large Projects in the Study Area not Within a Sample TAZ

TAZ	Development	Expected Residents	Commercial Square Feet	Expected Jobs	Current Study
19	South Station	5,590	4,190,000	14,304	South Station Expansion
135	Seaport Square	5,405	2,715,728	11,326	South Boston Waterfront Transportation Plan
136	Seaport Square	6,535	1,901,330	6,071	South Boston Waterfront Transportation Plan
139	Parcel A-2, Summer St., Seaport Square	0	1,325,850	4,535	South Boston Waterfront Transportation Plan
140	Waterfront Development/Parcel K	702	1,749,678	6,558	South Boston Waterfront Transportation Plan
144	HQ hotels and housing	5,022	2,773,340	11,468	South Boston Waterfront Transportation Plan
148	Boston Convention and Exhibition Center	0	3,026,984	8,068	South Boston Waterfront Transportation Plan
244	Harvard/Allston	1,513	3,256,000	5,882	Allston Interchange Traffic Study
502	Wynn Casino	492	2,901,673	7,012	Everett Transit Needs

TAZ = transportation analysis zone

Source: MAPC regional development database.

Appendix B

Travel Demand Forecasting

A goal of this study is to identify the transportation impacts of a defined set of development projects and business expansions and relate these impacts to specific parts of the transportation system. This requires developing detailed base-year travel data and projecting these data to year 2040 with sufficient detail that the impacts of individual projects can be identified.

To develop base-year and projected travel data at the required level of detail, staff has utilized a variety of data sources to build base-year data, and a combination of model and off-model techniques to make projections to 2040. The availability of useful base-year data and forecasting techniques vary by mode, submode, or type of projection. Some of the simpler data development and forecasting procedures are described in the main text. This appendix discusses some of the data development and projection approaches that were not described in the report.

Transit Forecasting

Detailed operational data of the four rapid transit lines were collected by the MBTA in 2012. Passenger entrances through turnstiles at rapid transit stations were obtained for the same period as the operational data. Using these two data sources it was possible to calculate the passenger loads and crowding levels between adjacent pairs of rapid transit stations by direction for each 15-minute interval during the AM and PM peak periods. These were the most detailed data developed for this study and became the basis of the rapid transit crowding analyses. Green Line and Mattapan Line stations not accessed through turnstiles could not be analyzed in this manner, and the Silver Line services were analyzed using calculations specifically developed for bus-vehicle services.

The No-Build Scenario assumed significant broad-based growth in regional travel demand. For the rapid transit system, it was assumed that the ridership growth that had been observed at individual rapid stations between 1997 and 2013 would continue at the same rate through year 2040. Projected increases varied between stations, and ridership increases between adjacent stations were estimated by averaging the growth in boardings at the two individual stations. The projected added ridership was allocated to directions, peak periods, and 15-minute intervals based on travel patterns observed in the 2012 Base Year.

Growth in the Build Scenario was based on detailed analyses of new trips that the 72 selected large-impact projects would be expected to generate. New trips were estimated for each project individually based on the population and types of jobs that are expected to be added at each location. The increased trips from the 72 projects were then grouped into the 20 sample TAZs.

The shares of new Build-Scenario trips in the 20 Sample TAZs that would use transit were assumed to be the same mode shares as in the Base Year. Estimates of transit mode shares by trip type and TAZ were derived from the Boston MPO regional travel demand model. The projected new transit riders were then added to the No-Build Scenario ridership, and peak-period boardings were increased accordingly at the rapid transit stations that would best serve the Build Scenario developments. Use of the rapid transit system by the new riders was assumed to reflect Base Year travel patterns.

Highway Modeling

Unlike the transit forecasts, which could assume an increase in boardings at specific stations on a well-defined system, traffic forecasts rely on the regional travel demand model to allocate new traffic to the myriad of paths available to motorists going to or leaving a new development. The network of major highways and arterial roads used in the model is extensive, including roads stretching from New Hampshire to Rhode Island and Cape Cod. As a general rule, extensive traffic models used to study a smaller area undergo a process known as calibration, in which trips generated by certain TAZs are adjusted so that traffic volumes estimated in the traffic assignment model step reasonably match traffic counts on study area roadways. This study was able to utilize a version of the regional model which had undergone extensive calibration as part of Allston I-90 Interchange Study.

The calibrated Base Year trips were increased by a set of factors by vehicle type to provide an estimate of 2040 traffic. These factors were calculated from another region-wide modeling effort, the Route 3 South Project Mobility Study. The factors derived from this study were:

12.5 percent	Single-occupancy vehicles (SOVs)
11.5 percent	High-occupancy vehicles (HOVs)
11.8 percent	Large trucks (6+ wheels)
9.0 percent	Commercial vans and pickup trucks
19.1 percent	Hazardous cargoes

The trips by vehicle type obtained after multiplying by these factors were used to estimate the Build Scenario traffic volumes. This is because substantially all the projects envisioned for 2040 in the 20 sample TAZs were assumed in Year 2040 for the Route 3 study.

Vehicle trips in the 2040 No-Build Scenario were developed by subtracting the auto trips from the SOV and HOV trip tables that were estimated in the mode share calculations for the 72 large-impact projects described above in the Transit Forecasting section. For both the No-Build and Build scenarios, the geographic distribution of trip trips between home, work, and other destinations reflected the trip distribution patterns assumed for the Boston Region MPO's Long Range Transportation Plan (LRTP).

Appendix C

Roadway Congestion

This appendix summarizes traffic assignment results with tables and graphics for the Base Year, No-Build, and Build scenarios. The assignment step of the regional travel demand model allocates vehicle traffic to the roads included in the regional model network. The assigned volumes are compared with estimates of the capacities of network roadways, which indicate the presence and severity of roadway congestion.

The accompanying six figures show parts of the modeled roadway network where traffic volumes are estimated or predicted to exceed 85 percent of the roadway's capacity. Figures C-1, C-2, and C-3 show congested roadways during the AM peak period for the three modeled scenarios, and Figures C-4, C-5, and C-6 illustrate PM peak period congestion.

Each graphic is accompanied by a table listing the names of roadways that have congested sections in the Base Year, or gain additional congested sections in the future scenarios. The graphics have been prepared for readability and do not show all modeled roadways. The lists include all roads having or gaining congested sections, even if these congested roadway links are very short, or in some cases, not shown in the graphic.

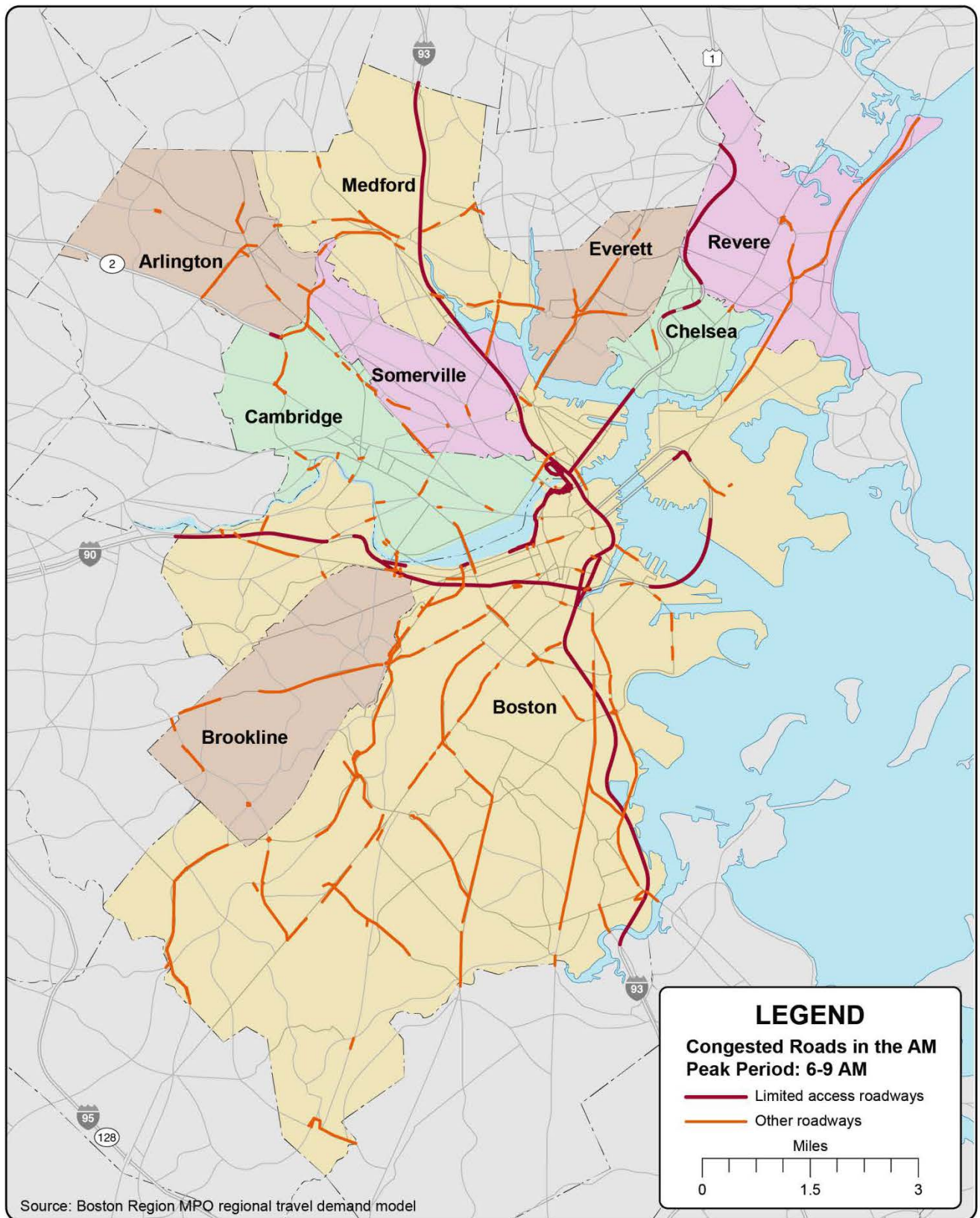
Base-Year Congested Links: AM Peak Period

Limited-Access Roadways

Interstate 90	<i>Boston (cont.)</i>	<i>Arlington</i>	<i>Chelsea</i>
Interstate 93	Massachusetts Ave	Broadway	Broadway
US Route 1	May St	Chestnut St	Everett Ave
Tobin Bridge	Melnea Cass Blvd	Massachusetts Ave	
Ted Williams Tunnel	Milton St	Medford St	<i>Everett</i>
Storrow Drive	Morrissey Blvd	Mystic St	Broadway
Soldiers Field Road	Morton St	Mystic Valley Pkwy	Main St
Route 2	N Beacon St	Pleasant St	Revere Beach Pkwy
	N Harvard St		

Other Roadways

<i>Boston</i>	N Washington St	<i>Brookline</i>	<i>Medford</i>
Arborway	Neponset Ave	Essex St	Fellsway
Austin St	Neponset Valley Pkwy	Hammond Pond Pkwy	Fellsway West
Beacon St	Old Colony Ave	Route 9	High St
Beacon St	Parsons St	W Roxbury Pkwy	Mystic Valley Pkwy
Belgrade Ave	Purchase St		Revere Beach Pkwy
Birmingham Pkwy	Riverway	<i>Cambridge</i>	Roosevelt Circle
Blue Hill Ave	Route 1A	Alewife Brook Pkwy	Salem St
Boylston St	Seaport Blvd	Brattle St	Winthrop St
Brookline Ave	South St	Broadway	
BU Bridge	Southampton St	Eliot Bridge	<i>Revere</i>
Cambridge St	Spring St	Fresh Pond Pkwy	American Legion Hwy
Centre St	State St	Gerry's Landing Rd	Broadway
Charlesgate Overpass	Summer St	JFK St	Lee Burbank Hwy
Columbia Rd	Tremont St	Land Blvd	North Shore Rd
Columbia Ave	University Rd	Main St	
Commonwealth Ave	VFW Pkwy	Massachusetts Ave	<i>Somerville</i>
Cummins Hwy	W Roxbury Pkwy	Memorial Dr	Alewife Brook Pkwy
Dorchester Ave	Washington St	Prospect St	Beacon St
Eliot Bridge		Reid Rotary	Fellsway
Embankment Rd		Western Ave	McGrath Hwy
Freeport St			Mystic Valley Pkwy
Frontage Rd (I-93)			Somerville Ave
Gallivan Blvd			
Granite Ave			
Harvard Ave			
Huntington Ave			
Hyde Park Ave			
Jamaica Way			
L Street			
Logan Airport Rd			
Maffa Way			
Mass Ave Connector			



**BOSTON
REGION
MPO**



FIGURE C-1
Location of Base-Year Scenario
AM Congested Roadway Links

*Core
Capacity
Constraints*

Year 2040 No-Build Scenario Congested Links: AM Peak Period

Limited-access roadways adding congested links

Interstate 90
Interstate 93
US Route 1
Tobin Bridge
Ted Williams Tunnel
Storrow Drive
Soldiers Field Road
Route 2

Limited-access roadways first showing congestion in this scenario

Leverett Connector
Sumner Tunnel
Callahan Tunnel

Other roadways already with congested sections adding congested links

Boston
Austin St
Beacon St
Boylston St
Brookline Ave
BU Bridge
Cambridge St
Charlesgate Overpass
Commonwealth Ave
Embankment Rd
Frontage Road (I-93)
Harvard Ave
Huntington Ave
Logan Airport Rd
Massachusetts Ave
N Beacon St
Stuart St
University Rd

Arlington
Massachusetts Ave
Mystic St
Pleasant St

Brookline
Route 9
West Roxbury Pkwy

Cambridge
Alewife Brook Pkwy
Fresh Pond Pkwy
Gerry's Landing Rd
Massachusetts Ave
Prospect St
Reid Rotary

Medford
Fellsway
High St
Revere Beach Pkwy
Salem St
Winthrop St

Revere
Broadway

Somerville
McGrath Hwy
Somerville Ave

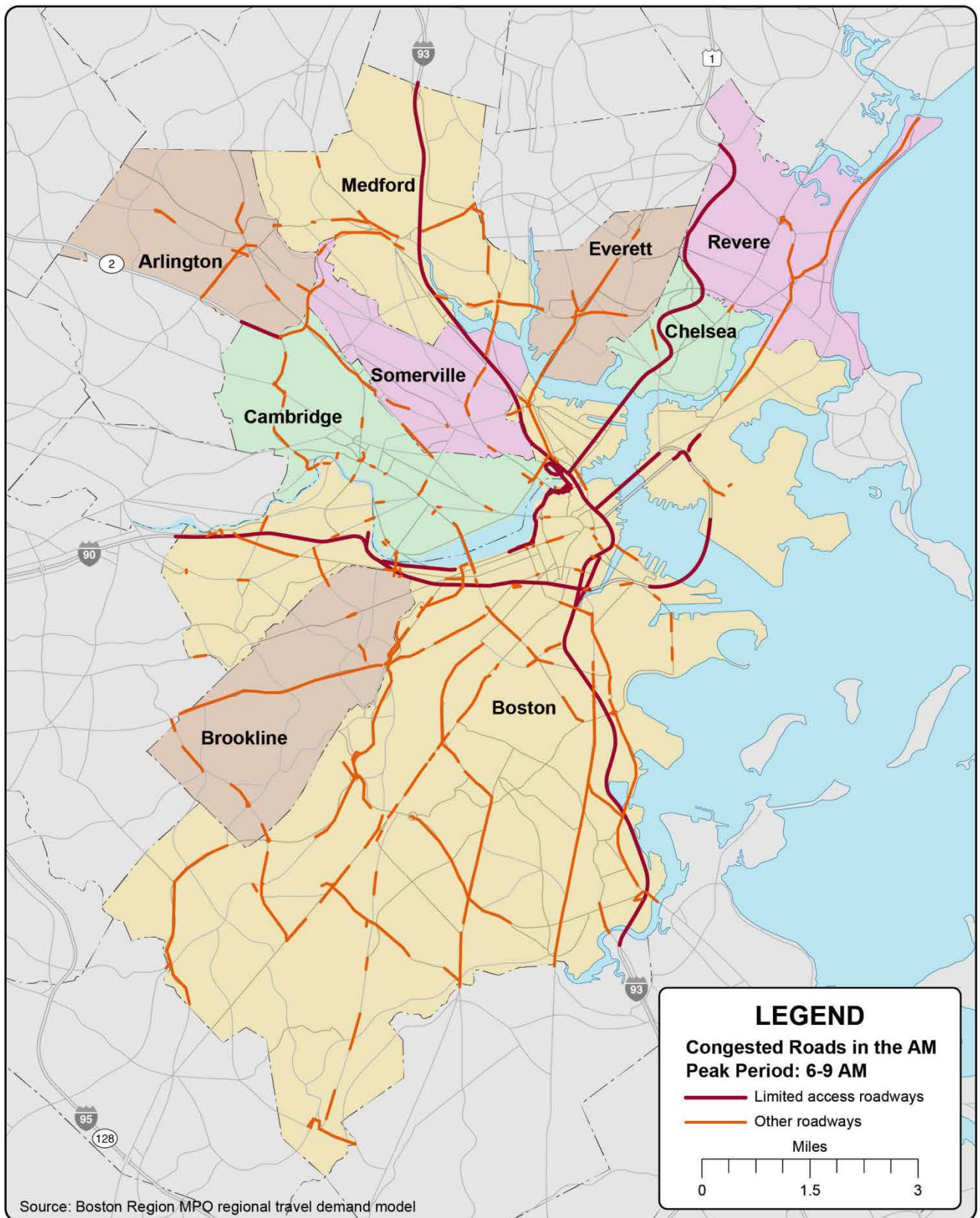
Other roadways first showing congestion in this scenario

Boston
Atlantic Ave
Bedford St
Bigelow St
Broadway
Herald St
New Chardon St
Nonantum Rd
Pearl St
Rutherford Ave

Brookline
Beacon St
Harvard St
South St

Cambridge
Mount Auburn St
Msgr O'Brien Hwy
Sidney St

Revere
Copeland Circle



**BOSTON
 REGION
 MPO**

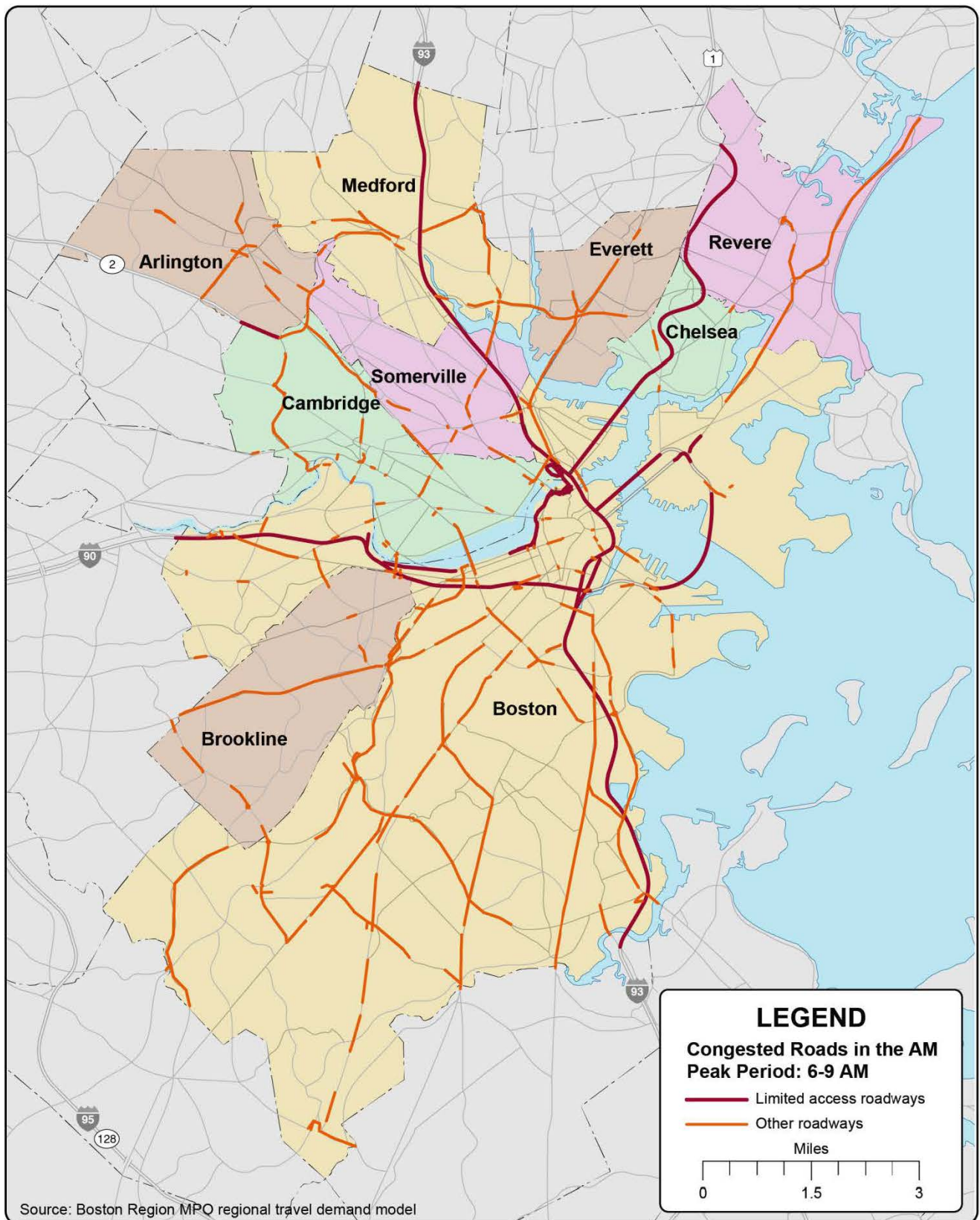


FIGURE C-2
Location of Future Year No-Build Scenario
AM Congested Roadway Links

*Core
 Capacity
 Constraints*

Year 2040 Build Scenario Congested Links: AM Peak Period

<u>Limited-access roadways adding congested links</u>	<u>Other roadways already with congested sections adding congested links</u>	<u>Other roadways first showing congestion in this scenario</u>
Interstate 90	<i>Boston</i>	<i>Boston</i>
Interstate 93	Arborway	Charles River Dam
Tobin Bridge	Beacon St	Charles Street South
	Boylston St	Day Blvd
	Cambridge St	Harborside Drive
	Columbus Ave	Preble St
	Dorchester Ave	West Fourth Street
	Embankment Road	West Roxbury Pkwy
	Freeport St	
	Frontage Road (I-93)	<i>Cambridge</i>
	Hyde Park Ave	Hampshire St
	Mass Ave Connector	
	Massachusetts Ave	<i>Chelsea</i>
	N Beacon St	Pearl St
	Riverway	
	Stuart St	<i>Somerville</i>
	Tremont St	Prospect St
	VFW Pkwy	Washington St
	Washington St	
	<i>Arlington</i>	
	Broadway	
	Medford St	
	Mystic Valley Pkwy	
	<i>Brookline</i>	
	Route 9	
	<i>Cambridge</i>	
	Fresh Pond Pkwy	
	Gerry's Landing Rd	
	Massachusetts Ave	
	Mount Auburn St	
	Msgr O'Brien Hwy	
	<i>Everett</i>	
	Broadway	
	Revere Beach Pkwy	
	<i>Medford</i>	
	Fellsway	
	Revere Beach Pkwy	
	<i>Somerville</i>	
	Beacon St	
	McGrath Hwy	



**BOSTON
REGION
MPO**



FIGURE C-3
Location of Future Year Build Scenario
AM Congested Roadway Links

*Core
Capacity
Constraints*

Base-Year Congested Links: PM Peak Period

Limited-Access Roadways

Interstate 90
Interstate 93
US Route 1
Tobin Bridge
Leverett Connector
Sumner Tunnel
Callahan Tunnel
Ted Williams Tunnel
Storrow Drive
Soldiers Field Road
Route 2

Other Roadways

Boston

Adams St
Alford St
Arborway
Austin St
Beacon St
Belgrade Ave
Berkeley St
Blue Hill Ave
Boylston St
Brookline Ave
BU Bridge
Cambridge St
Casey Hwy
Centre St
Charles River Dam
Charles St South
Charlesgate Overpass
Columbia Rd
Commonwealth Ave
Congress St
Court St
Cross St
Cummins Hwy
D St
Dorchester Ave
E Berkeley St
Eliot Bridge
Embankment Rd
Endicott St
Essex St
Faneuil St

Boston (cont.)

Freeport St
Gallivan Blvd
Granite Ave
Haul Rd
Herald St
Huntington Ave
Hyde Park Ave
Jamaicaway
Kneeland St
L St
Logan Airport Rd
Main St
Market St
Mass Ave Connector
Massachusetts Ave
Melnea Cass Blvd
Meridian St
Milton St
Morrissey Blvd
Morton St
Mystic Ave
N Beacon St
N Harvard St
N Washington St
Neponset Ave
Neponset Valley Pkwy
New Chardon St
Nonantum Rd
Old Colony Ave
Porter St
Purchase St
Riverway
Rte 1A
Rutherford Ave
Seaport Blvd
Spring St
St. James Ave
State St
Stuart St
Sudbury St
Sullivan Sq
Summer St
Tremont St
VFW Pkwy
W Roxbury Pkwy
Washington St

Arlington

Broadway
Massachusetts Ave
Medford St
Mystic St
Pleasant St

Brookline

Beacon St
Brookline Ave
Grove St
Hammond Pond Pkwy
Harvard St
Route 9
W Roxbury Pkwy

Cambridge

Alewife Brook Pkwy
Brattle St
Broadway
Cambridge St
Charlestown Ave
Concord Ave
Fresh Pond Pkwy
Gerry's Landing Rd
Hampshire St
Land Blvd
Main St
Massachusetts Ave
Memorial Dr
Mount Auburn St
Msgr O'Brien Hwy
Peabody St
Prospect St
Sidney St
Somerville Ave
Waterhouse St
Western Ave

Chelsea

Broadway
Everett Ave
Pearl St
Revere Beach Pkwy

Everett

Alford St
Broadway
Main St
Revere Beach Pkwy

Medford

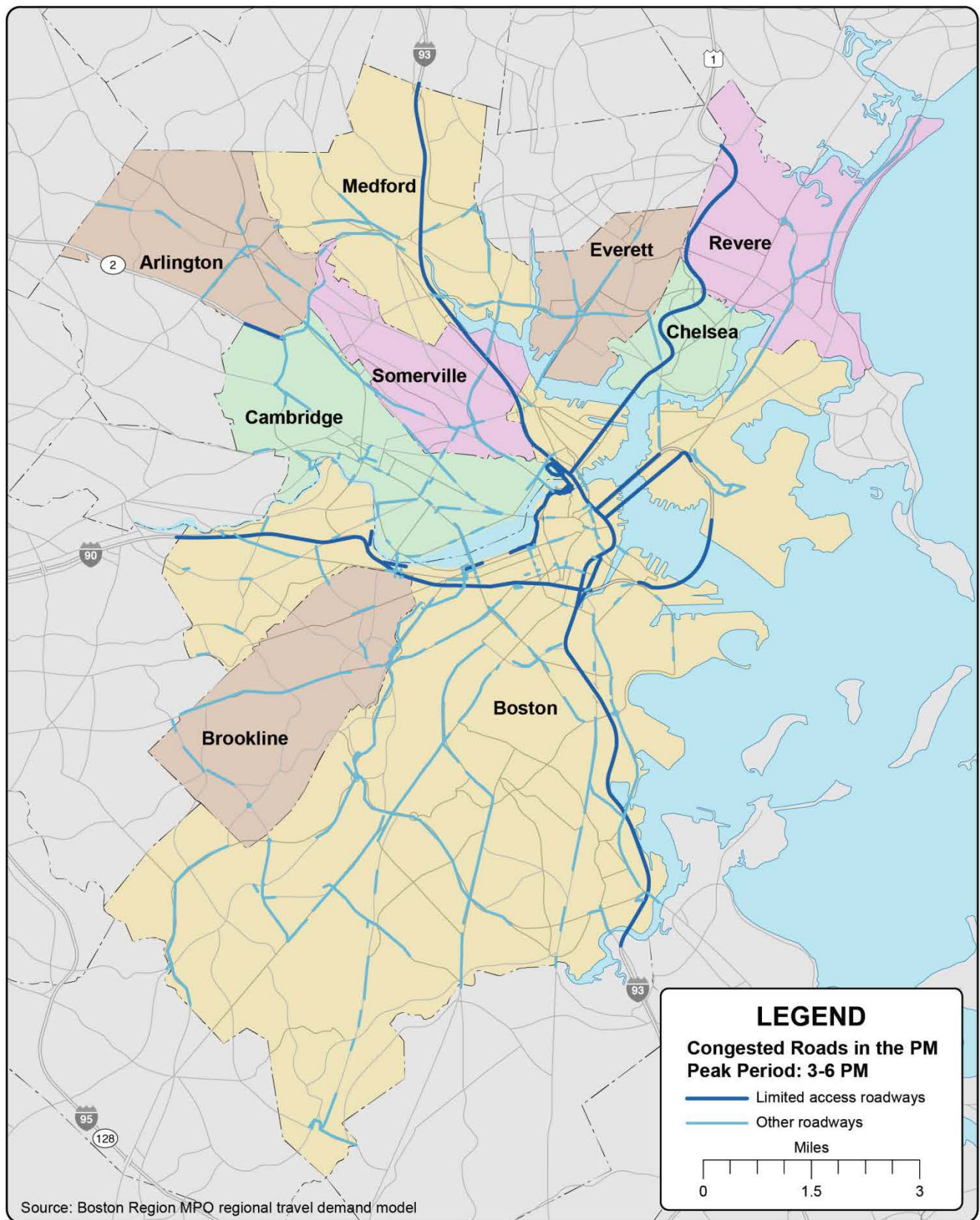
Fellsway
Fellsway West
High St
Mystic Valley Pkwy
Salem St
Winthrop St

Revere

American Legion Hwy
Cutler Hwy
Lee Burbank Hwy
North Shore Rd
VFW Pkwy

Somerville

Alewife Brook Pkwy
Beacon St
Fellsway
McGrath Hwy
Mystic Ave
Mystic Valley Pkwy
Prospect St
Somerville Ave
Washington St



**BOSTON
REGION
MPO**

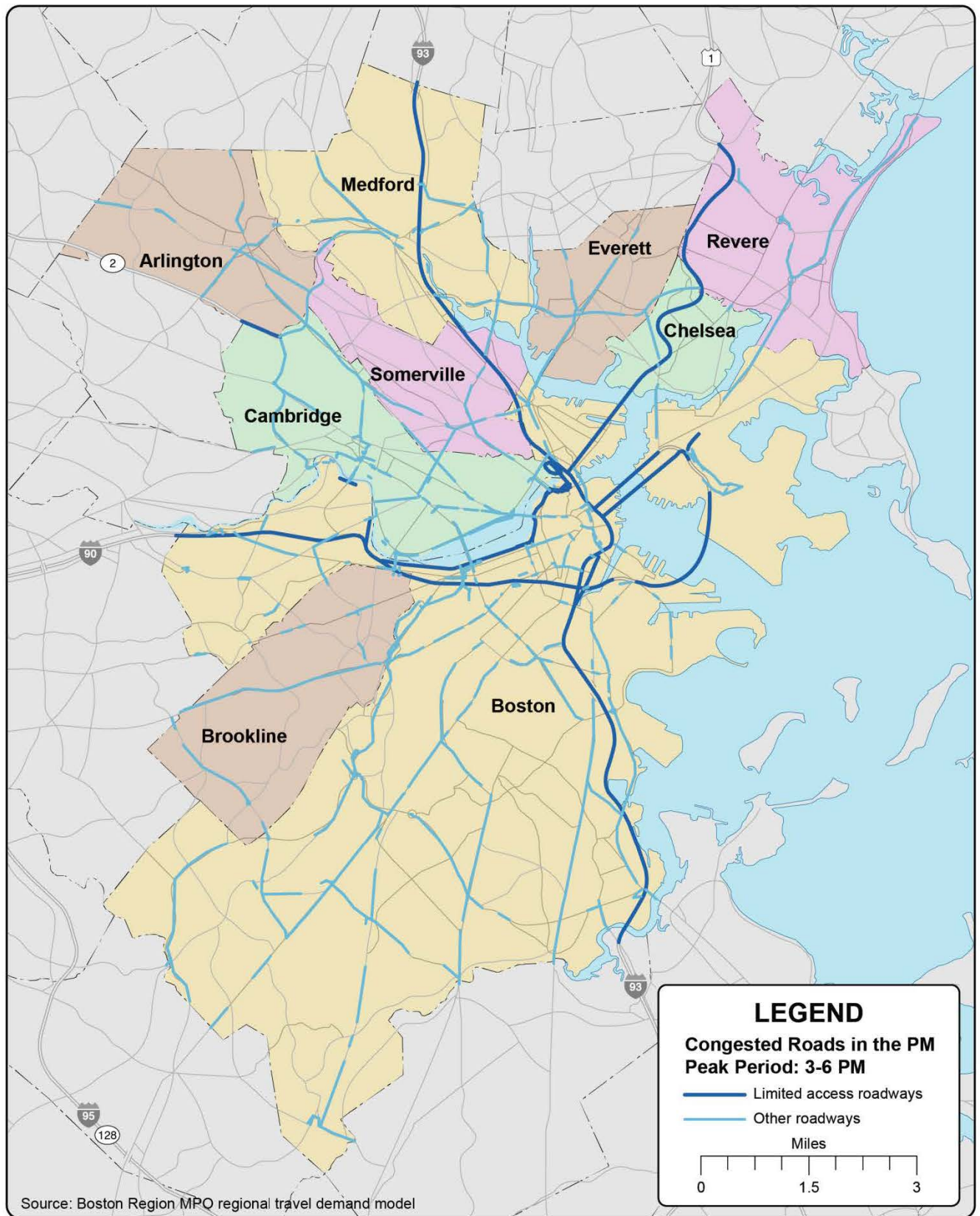


FIGURE C-4
Location of Base-Year Scenario
PM Congested Roadway Links

*Core
Capacity
Constraints*

Year 2040 No-Build Scenario Congested Links: PM Peak Period

<u>Limited-access roadways adding congested links</u>	<u>Other roadways already with congested sections adding congested links (cont.)</u>	<u>Other roadways first showing congestion in this scenario</u>
Interstate 90	<i>Arlington</i>	<i>Boston</i>
Interstate 93	Broadway	Atlantic Ave
US Route 1	Massachusetts Ave	Broadway
Storrow Drive	Medford St	Columbus Ave
<u>Other roadways already with congested sections adding congested links</u>	Mystic St	Frontage Rd
<i>Boston</i>	<i>Brookline</i>	Harvard Ave
Alford St	Beacon St	High St
Beacon St	Harvard St	Park Dr
Belgrade Ave	Route 9	Park St
Blue Hill Ave	<i>Cambridge</i>	Pearl St
BU Bridge	Concord Ave	Preble St
Cambridge St	Fresh Pond Pkwy	Seaver St
Centre St	Main St	University Rd
Charles St South	Massachusetts Ave	<i>Arlington</i>
Commonwealth Ave	Memorial Dr	Mystic Valley Pkwy
Congress St	Mount Auburn St	<i>Brookline</i>
Cross St	Prospect St	South St
Dorchester Ave	<i>Chelsea</i>	<i>Cambridge</i>
Eliot Bridge	Everett Ave	Cambridge Pkwy Connector
Embankment Rd	Revere Beach Pkwy	JFK St
Essex St	<i>Everett</i>	<i>Revere</i>
Freeport St	Broadway	Squire Rd
Granite Ave	Revere Beach Pkwy	<i>Somerville</i>
Herald St	<i>Medford</i>	Lombardi Way
Huntington Ave	Fellsway	
Hyde Park Ave	Fellsway West	
Jamaicaway	High St	
L St	Mystic Valley Pkwy	
Logan Airport Rd	Salem St	
Massachusetts Ave	Winthrop St	
Melnea Cass Blvd	<i>Revere</i>	
Meridian St	American Legion Hwy	
Morrissey Blvd	Lee Burbank Hwy	
Morton St	<i>Somerville</i>	
N Beacon St	Beacon St	
Nonantum Rd	Fellsway	
Old Colony Ave	McGrath Hwy	
Riverway	Prospect St	
Rutherford Ave	Somerville Ave	
Seaport Blvd	Washington St	
St James Ave		
State St		
Summer St		
Tremont St		
Washington St		



**BOSTON
REGION
MPO**

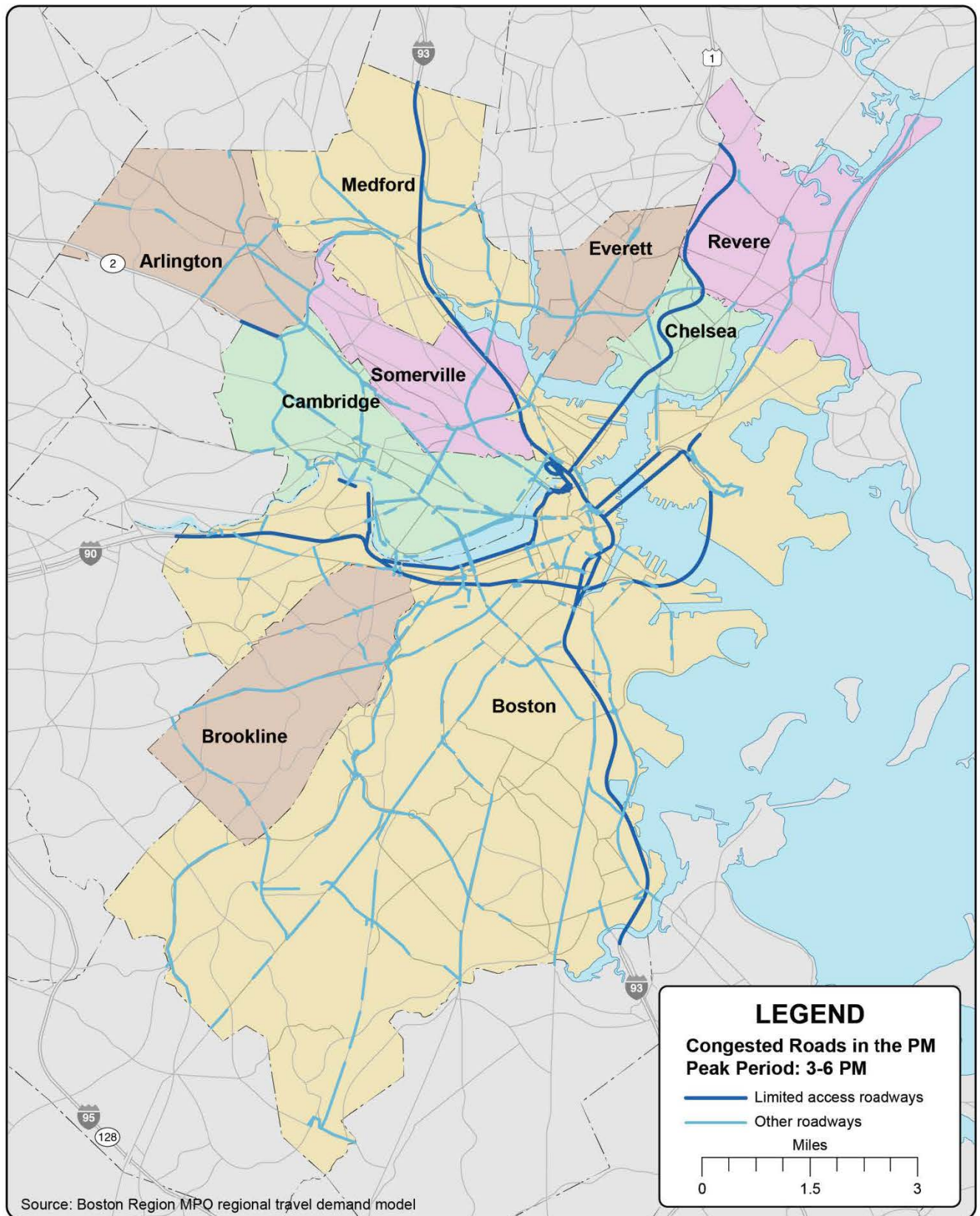


FIGURE C-5
Location of Future Year No-Build Scenario
PM Congested Roadway Links

*Core
Capacity
Constraints*

Year 2040 Build Scenario Congested Links: PM Peak Period

<u>Limited-access roadways adding congested links</u>	<u>Other roadways already with congested sections adding congested links (cont.)</u>	<u>Other roadways first showing congestion in this scenario</u>
US Route 1 Storrow Dr Soldiers Field Rd	<i>Brookline</i> Route 9 <i>Cambridge</i> Concord Ave Hampshire St Land Blvd Main St Massachusetts Ave Msgr O'Brien Hwy Prospect St	<i>Boston</i> Agassiz Rd Arlington St Charles St Circle Charlesgate East Kosciuszko Circle Mugar Way North St West 4th Street (SE Xway)
<u>Other roadways already with congested sections adding congested links</u> <i>Boston</i> Beacon St Berkeley St Columbus Ave Dorchester Ave Frontage Rd (SE Xway) Huntington Ave Hyde Park Ave Jamaica Way Kneeland St L Street Logan Airport Rd Mass Ave Connector Massachusetts Ave Meridian St Morrissey Blvd Rutherford Ave State St Stuart St Washington St	<i>Everett</i> Broadway Revere Beach Pkwy <i>Medford</i> Fellsway <i>Revere</i> American Legion Hwy Lee Burbank Hwy Squire Rd <i>Somerville</i> McGrath Hwy Somerville Ave Washington St	<i>Brookline</i> River Rd <i>Cambridge</i> Magazine St River St



**BOSTON
REGION
MPO**



FIGURE C-6
Location of Future Year Build Scenario
PM Congested Roadway Links

*Core
Capacity
Constraints*

Reverse of Figure C-6

Appendix D

Base Year Rapid Transit Service Frequencies

Appendix D shows average observed service frequencies. These are calculated for the midpoint of the Red, Orange, and Blue Lines, and for the start of the Green Line trips.

Base Year Rapid Transit Service Frequencies

Average Number of Trains Observed per 15-Minute Interval

AM Peak Period	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
Red Line Southbound	2.1	1.7	3.3	2.3	2.7	3.0	3.2	3.0	3.5	3.5	3.1	3.1	3.1
Red Line Northbound	3.0	2.4	3.5	3.0	3.0	3.8	3.9	3.0	3.4	3.8	3.6	3.6	3.3
Orange Line Southbound	1.3	1.6	1.9	2.0	2.9	2.5	2.7	3.1	2.8	2.6	2.0	2.7	2.2
Orange Line Northbound	1.1	1.8	1.9	1.9	2.9	3.0	2.8	2.9	2.5	3.0	2.7	2.7	2.8
Green Line Westbound	6.8	5.9	6.8	7.4	9.1	9.2	9.1	8.9	9.1	8.2	9.4	9.4	8.6
Green Line Eastbound	6.4	6.3	9.4	9.0	10.0	10.0	8.1	10.9	9.2	8.6	9.2	9.2	10.0
Blue Line Southbound	2.8	2.5	3.6	2.8	3.1	3.2	3.4	3.0	3.8	3.1	3.3	3.3	3.2
Blue Line Northbound	2.1	2.2	1.8	3.1	3.6	2.9	3.7	3.3	3.1	3.2	3.6	3.6	2.9
PM Peak Period	3:00PM	3:15PM	3:30PM	3:45PM	4:00PM	4:15PM	4:30PM	4:45PM	5:00PM	5:15PM	5:30PM	5:45PM	6:00PM
Red Line Southbound	2.0	2.2	2.4	3.0	2.3	3.0	3.0	3.0	4.0	3.8	3.9	3.9	3.5
Red Line Northbound	2.5	3.4	3.5	2.5	3.7	3.3	2.9	2.9	3.7	2.9	3.2	3.2	3.7
Orange Line Southbound	2.0	1.8	2.2	2.0	2.8	3.0	2.6	2.7	2.9	2.9	2.8	2.8	2.7
Orange Line Northbound	2.0	2.5	2.8	2.1	2.5	3.1	2.9	3.0	2.6	2.7	2.6	2.6	2.6
Green Line Westbound	7.4	7.4	6.8	7.3	8.7	8.7	9.4	9.3	7.8	6.1	8.7	8.7	9.8
Green Line Eastbound	7.6	7.7	7.9	7.8	9.1	8.0	8.9	9.0	7.8	9.9	8.6	8.6	8.0
Blue Line Southbound	2.5	3.0	3.1	3.4	3.3	2.9	3.1	3.7	3.1	3.1	3.0	3.0	3.7
Blue Line Northbound	3.3	3.1	3.5	3.1	3.1	3.3	3.4	3.0	3.0	3.6	3.3	3.3	3.0

Red Line Frequencies are for Ashmont and Braintree services combined between Alewife and JFK/Umass.

Green Line Frequencies are for B, C, D, and E Line services combined between Copley and Park Street.

Appendix E

Base Year Passengers by Route Segment and Time Period

Appendix E shows the total passengers traveling between each pair of adjacent stations by direction for each peak-period 15-minute interval.

Passengers by Route Segment and Time Period
Red Line Southbound - AM
Base Year

Route Segment (Branch)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM -															
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM				
Alewife-Davis	44	76	131	221	211	335	458	549	560	610	658	605				
Davis-Porter	97	133	257	404	413	639	854	1,085	1,167	1,291	1,440	1,351				
Porter-Harvard	131	172	317	580	501	779	1,192	1,494	1,582	1,682	2,079	1,722				
Harvard-Central	183	221	425	649	605	969	1,401	1,648	1,770	2,021	2,355	1,957				
Central-Kendall	211	294	489	714	691	1,086	1,502	1,791	2,020	2,366	2,626	2,276				
Kendall-Charles/MGH	206	292	466	651	668	1,050	1,403	1,610	1,847	2,164	2,302	2,016				
Charles/MGH-Park St	173	243	363	520	605	932	1,266	1,432	1,702	1,985	2,096	1,851				
Park St-Downtown Crossing	185	268	357	521	669	884	1,087	1,157	1,423	1,593	1,647	1,331				
Downtown Crossing-South Station	227	369	446	610	864	1,016	1,111	1,086	1,323	1,446	1,425	1,153				
South Station-Broadway	158	259	326	440	655	691	608	494	544	547	517	492				
Broadway-Andrew	153	244	298	427	623	666	568	453	492	509	482	459				
Andrew-JFK/UMASS	135	207	283	413	604	637	555	433	466	490	465	432				
JFK/UMASS-N Quincy (Braintree)	91	108	128	180	252	277	238	213	216	204	175	161				
N Quincy-Wollaston (Braintree)	78	95	99	148	204	179	162	140	147	128	125	124				
Wollaston-Quincy Ctr (Braintree)	79	92	95	156	212	165	147	129	137	120	114	128				
Quincy Ctr-Quincy Adams (Braintree)	54	61	55	63	77	71	62	66	55	51	44	45				
Quincy Adams-Braintree (Braintree)	31	33	35	30	45	33	23	21	24	15	17	16				
JFK/UMASS-Savin Hill (Ashmont)	53	83	108	154	146	121	106	89	91	91	84	68				
Savin Hill-Fields Corner (Ashmont)	53	77	102	110	118	111	98	87	87	81	76	66				
Fields Corner-Shawmut (Ashmont)	53	59	101	113	103	93	71	64	70	53	52	56				
Shawmut-Ashmont (Ashmont)	51	58	99	109	95	82	57	53	50	46	40	50				

Passengers by Route Segment and Time Period
Red Line Northbound - PM
Base Year

Route Segment (Branch)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Davis-Alewife	186	194	217	255	359	368	445	479	617	571	493	466
Porter-Davis	352	381	423	471	616	643	772	920	1,263	1,197	1,099	1,050
Harvard-Porter	465	501	565	593	822	988	999	1,243	1,745	1,608	1,460	1,400
Central-Harvard	641	715	781	811	1,044	1,239	1,305	1,545	2,178	2,084	1,873	1,740
Kendall-Central	730	797	881	922	1,148	1,302	1,429	1,617	2,393	2,364	2,208	1,982
Charles/MGH-Kendall	725	787	851	878	1,063	1,125	1,328	1,382	2,131	2,171	2,031	1,815
Park St-Charles/MGH	753	786	797	843	997	1,046	1,203	1,263	1,927	2,017	1,888	1,692
Downtown Crossing-Park St	697	763	775	805	816	937	1,008	1,096	1,506	1,728	1,655	1,351
South Station-Downtown Crossing	783	894	934	949	836	969	1,068	1,155	1,364	1,657	1,661	1,297
Broadway-South Station	634	731	751	754	549	652	641	695	629	788	838	615
Andrew-Broadway	610	705	725	708	527	615	607	654	577	712	780	583
JFK/UMASS-Andrew	574	660	649	644	481	552	573	603	537	648	724	550
N Quincy-JFK/UMASS (Braintree)	218	247	246	259	200	250	285	287	248	316	336	276
Wollaston-N Quincy (Braintree)	184	211	205	214	156	197	219	223	201	190	226	213
Quincy Ctr-Wollaston (Braintree)	180	189	179	191	141	169	204	205	174	167	207	198
Quincy Adams-Quincy Ctr (Braintree)	67	69	96	104	74	86	110	121	101	80	109	123
Braintree-Quincy Adams (Braintree)	49	41	57	56	47	57	69	53	50	37	59	40
Savin Hill-JFK/UMASS (Ashmont)	238	254	229	208	171	186	180	177	183	178	170	132
Fields Corner-Savin Hill (Ashmont)	227	223	177	184	153	158	157	159	168	153	145	115
Shawmut-Fields Corner (Ashmont)	195	218	120	123	111	109	116	114	114	99	95	86
Ashmont-Shawmut (Ashmont)	179	204	95	101	92	90	101	91	92	83	69	71

Passengers by Route Segment and Time Period
Red Line Northbound - AM
Base Year

Route Segment (Branch)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM -															
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM				
Davis-Alewife	90	96	117	114	128	166	175	166	189	173	117	110				
Porter-Davis	102	102	150	153	190	226	221	216	245	269	192	181				
Harvard-Porter	112	131	180	192	250	278	270	273	291	333	257	229				
Central-Harvard	213	281	344	364	475	562	607	600	668	831	767	535				
Kendall-Central	249	344	419	480	605	710	761	750	845	993	969	629				
Charles/MGH-Kendall	299	454	582	643	778	955	1,084	1,115	1,259	1,543	1,442	1,010				
Park St-Charles/MGH	456	709	941	914	1,003	1,196	1,389	1,357	1,468	1,719	1,599	1,145				
Downtown Crossing-Park St	489	763	1,104	1,214	1,334	1,554	1,803	1,833	2,030	2,277	2,104	1,680				
South Station-Downtown Crossing	552	870	1,296	1,438	1,533	1,795	2,063	2,203	2,494	2,674	2,496	2,146				
Broadway-South Station	636	814	1,299	1,398	1,541	1,847	2,202	2,275	2,629	2,772	2,731	2,483				
Andrew-Broadway	623	790	1,267	1,391	1,515	1,805	2,138	2,212	2,517	2,613	2,569	2,353				
JFK/UMASS-Andrew	586	739	1,199	1,375	1,451	1,759	2,057	2,116	2,407	2,488	2,458	2,236				
N Quincy-JFK/UMASS (Braintree)	313	437	637	722	885	1,034	1,414	1,401	1,610	1,583	1,587	1,451				
Wollaston-N Quincy (Braintree)	255	357	530	591	725	839	1,176	1,163	1,283	1,263	1,256	1,101				
Quincy Ctr-Wollaston (Braintree)	195	294	416	465	585	657	938	912	1,022	959	987	881				
Quincy Adams-Quincy Ctr (Braintree)	132	180	279	308	362	416	597	573	648	521	529	503				
Braintree-Quincy Adams (Braintree)	82	116	194	184	232	271	376	380	366	252	181	206				
Savin Hill-JFK/UMASS (Ashmont)	257	273	518	629	585	755	750	799	747	801	799	747				
Fields Corner-Savin Hill (Ashmont)	243	237	467	569	552	721	704	717	634	674	697	645				
Shawmut-Fields Corner (Ashmont)	175	172	316	416	408	552	548	534	528	541	575	522				
Ashmont-Shawmut (Ashmont)	146	114	249	334	321	448	419	431	399	416	448	405				

Passengers by Route Segment and Time Period
Red Line Southbound - PM
Base Year

Route Segment (Branch)	3:00PM - 3:15PM - 3:30PM - 3:45PM - 4:00PM - 4:15PM - 4:30PM - 4:45PM - 5:00PM - 5:15PM - 5:30PM - 5:45PM - 6:00PM													
	3:15PM	3:30PM	3:45PM	4:00PM	4:15PM	4:30PM	4:45PM	5:00PM	5:15PM	5:30PM	5:45PM	6:00PM		
Alewife-Davis	79	97	94	98	81	118	148	152	144	194	203	195		
Davis-Porter	179	205	182	200	175	204	260	271	238	328	336	307		
Porter-Harvard	222	271	231	258	228	268	314	348	311	451	415	381		
Harvard-Central	440	598	553	576	479	657	623	644	684	983	805	717		
Central-Kendall	531	686	675	676	606	782	772	785	891	1,198	973	860		
Kendall-Charles/MGH	625	788	806	776	835	979	1,036	1,071	1,308	1,685	1,294	1,148		
Charles/MGH-Park St	741	896	1,071	917	1,044	1,132	1,336	1,263	1,580	1,856	1,469	1,273		
Park St-Downtown Crossing	905	1,076	1,201	1,151	1,383	1,353	1,690	1,635	2,134	2,211	1,723	1,520		
Downtown Crossing-South Station	1,013	1,206	1,300	1,269	1,530	1,511	1,923	1,920	2,484	2,481	1,937	1,683		
South Station-Broadway	1,007	1,185	1,245	1,259	1,540	1,551	1,905	2,050	2,821	2,537	2,132	1,797		
Broadway-Andrew	1,002	1,159	1,222	1,222	1,535	1,527	1,869	2,022	2,754	2,461	2,052	1,751		
Andrew-JFK/UMASS	953	1,095	1,184	1,181	1,504	1,481	1,815	1,972	2,627	2,371	1,956	1,660		
JFK/UMASS-N Quincy (Braintree)	532	618	651	701	947	987	1,125	1,283	1,741	1,543	1,289	1,091		
N Quincy-Wollaston (Braintree)	451	517	559	590	781	813	904	1,045	1,423	1,254	1,029	870		
Wollaston-Quincy Ctr (Braintree)	378	424	466	472	624	676	719	833	1,149	992	819	708		
Quincy Ctr-Quincy Adams (Braintree)	215	242	292	286	380	400	429	485	671	541	464	382		
Quincy Adams-Braintree (Braintree)	127	135	168	177	225	229	250	260	333	266	210	169		
JFK/UMASS-Savin Hill (Ashmont)	419	437	480	475	527	484	618	620	792	740	607	509		
Savin Hill-Fields Corner (Ashmont)	417	412	437	438	475	439	555	563	699	654	542	427		
Fields Corner-Shawmut (Ashmont)	313	293	346	328	348	346	419	455	536	515	426	339		
Shawmut-Ashmont (Ashmont)	258	241	275	261	266	264	317	349	415	398	336	263		

Passengers by Route Segment and Time Period
Orange Line Southbound - AM
Base Year

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Oak Grove-Malden Ctr	102	123	198	177	343	374	483	412	434	529	463	345
Malden Ctr-Wellington	237	336	394	475	760	886	1,083	933	1,135	1,364	1,257	1,024
Wellington-Assembly	312	428	559	651	975	1,109	1,388	1,200	1,489	1,760	1,652	1,371
Assembly-Sullivan Sq	312	428	559	651	975	1,109	1,388	1,200	1,489	1,760	1,652	1,371
Sullivan Sq-Community College	454	583	692	817	1,154	1,274	1,625	1,506	1,804	2,084	1,955	1,617
Community College-North Station	463	596	690	811	1,141	1,305	1,635	1,513	1,781	2,057	1,979	1,642
North Station-Haymarket	386	571	702	733	1,161	1,308	1,664	1,645	2,081	2,047	2,160	1,642
Haymarket-State	416	651	760	793	1,215	1,354	1,687	1,662	2,118	2,056	2,179	1,631
State-Downtown Crossing	471	736	865	867	1,251	1,396	1,618	1,544	1,922	1,838	1,955	1,436
Downtown Crossing-Chinatown	428	623	797	794	1,071	1,275	1,416	1,381	1,669	1,594	1,715	1,316
Chinatown-Tufts Medical Ctr	385	584	738	726	1,000	1,185	1,305	1,261	1,513	1,428	1,518	1,155
Tufts Medical Ctr-Back Bay	342	514	631	626	855	1,021	1,113	1,074	1,268	1,214	1,316	1,000
Back Bay-Mass Ave	229	353	459	430	545	600	638	512	603	570	560	461
Mass Ave-Ruggles	214	333	424	410	502	547	566	454	515	499	473	380
Ruggles-Roxbury Crossing	131	216	271	264	292	283	242	235	238	240	229	170
Roxbury Crossing-Jackson Sq	115	177	229	217	227	215	210	202	199	196	185	138
Jackson Sq-Stony Brook	132	180	229	203	190	174	180	170	163	164	142	114
Stony Brook-Green St	141	178	233	202	183	164	174	158	144	150	116	94
Green St-Forest Hills	144	171	220	179	159	120	122	117	112	119	89	83

Passengers by Route Segment and Time Period

Orange Line Northbound - PM

Base Year

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Malden Ctr-Oak Grove	106	145	181	177	289	300	343	390	476	445	344	310
Wellington-Malden Ctr	347	402	487	476	665	724	818	916	1,209	1,109	944	826
Assembly-Wellington	469	543	662	646	882	933	1,091	1,155	1,578	1,427	1,246	1,079
Sullivan Sq-Assembly	469	543	662	646	882	933	1,091	1,155	1,578	1,427	1,246	1,079
Community College-Sullivan Sq	622	713	853	806	1,090	1,142	1,316	1,390	1,863	1,736	1,520	1,303
North Station-Community College	680	806	904	816	1,113	1,180	1,364	1,429	1,896	1,843	1,651	1,372
Haymarket-North Station	639	763	897	841	1,145	1,214	1,358	1,559	2,040	1,881	1,606	1,366
State-Haymarket	663	798	930	884	1,159	1,232	1,380	1,576	2,039	1,925	1,647	1,416
Downtown Crossing-State	719	926	1,038	955	1,204	1,232	1,364	1,489	1,882	1,863	1,562	1,385
Chinatown-Downtown Crossing	732	969	977	900	1,147	1,152	1,292	1,360	1,692	1,751	1,417	1,294
Tufts Medical Ctr-Chinatown	669	902	921	838	1,021	1,049	1,196	1,258	1,529	1,641	1,340	1,210
Back Bay-Tufts Medical Ctr	624	851	828	753	890	937	1,046	1,123	1,334	1,480	1,223	1,080
Mass Ave-Back Bay	478	719	681	626	648	652	699	764	740	843	721	648
Ruggles-Mass Ave	449	676	656	591	591	601	635	687	675	758	648	571
Roxbury Crossing-Ruggles	287	495	474	386	392	398	367	386	418	424	397	341
Jackson Sq-Roxbury Crossing	260	354	413	332	349	330	324	341	368	374	346	317
Stony Brook-Jackson Sq	222	320	375	277	298	263	264	274	292	273	273	255
Green St-Stony Brook	197	285	350	236	265	239	234	239	260	229	230	230
Forest Hills-Green St	176	263	260	166	232	203	188	196	218	188	190	176

Passengers by Route Segment and Time Period
Orange Line Northbound - AM
Base Year

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Malden Ctr-Oak Grove	13	17	16	21	19	14	16	22	19	12	14	16
Wellington-Malden Ctr	35	60	59	84	88	95	88	112	127	109	97	79
Assembly-Wellington	61	104	106	128	138	161	151	205	224	175	154	129
Sullivan Sq-Assembly	61	104	106	128	138	161	151	205	224	175	154	129
Community College-Sullivan Sq	108	194	212	246	275	294	291	330	343	298	260	215
North Station-Community College	125	264	358	368	345	367	418	539	608	466	374	320
Haymarket-North Station	167	325	466	473	474	505	601	724	752	706	586	558
State-Haymarket	179	346	508	526	538	570	708	850	868	849	737	737
Downtown Crossing-State	189	359	586	600	650	701	890	1,089	1,168	1,253	1,173	1,188
Chinatown-Downtown Crossing	226	383	648	722	816	950	1,103	1,308	1,363	1,594	1,583	1,564
Tufts Medical Ctr-Chinatown	227	386	657	725	820	962	1,128	1,351	1,400	1,656	1,669	1,643
Back Bay-Tufts Medical Ctr	236	408	673	727	804	1,000	1,196	1,422	1,508	1,766	1,730	1,710
Mass Ave-Back Bay	255	393	617	723	770	1,041	1,132	1,355	1,357	1,496	1,643	1,474
Ruggles-Mass Ave	253	382	586	705	749	996	1,072	1,285	1,291	1,403	1,564	1,415
Roxbury Crossing-Ruggles	247	308	547	653	750	1,020	1,031	1,255	1,244	1,341	1,510	1,363
Jackson Sq-Roxbury Crossing	237	296	527	648	769	1,025	1,019	1,203	1,175	1,243	1,430	1,262
Stony Brook-Jackson Sq	196	249	413	538	620	878	846	987	987	1,064	1,243	1,060
Green St-Stony Brook	178	217	366	485	554	782	737	849	826	898	1,027	834
Forest Hills-Green St	160	186	328	436	501	712	649	725	674	723	836	632

Passengers by Route Segment and Time Period
Orange Line Southbound - PM
Base Year

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Oak Grove-Malden Ctr	31	40	33	50	48	31	38	34	51	37	37	39
Malden Ctr-Wellington	132	174	158	167	147	171	178	169	185	200	159	159
Wellington-Assembly	183	240	238	249	212	277	256	267	286	320	269	231
Assembly-Sullivan Sq	183	240	238	249	212	277	256	267	286	320	269	231
Sullivan Sq-Community College	318	373	389	374	330	431	395	422	433	506	387	344
Community College-North Station	368	429	429	543	464	523	464	479	545	769	488	405
North Station-Haymarket	392	483	498	585	564	598	598	637	699	941	613	513
Haymarket-State	455	545	562	641	667	674	696	749	857	1,039	700	566
State-Downtown Crossing	560	616	667	709	809	815	899	974	1,271	1,306	935	767
Downtown Crossing-Chinatown	716	796	861	849	942	980	1,137	1,182	1,573	1,639	1,269	1,046
Chinatown-Tufts Medical Ctr	708	771	839	831	937	967	1,129	1,204	1,597	1,653	1,271	1,076
Tufts Medical Ctr-Back Bay	709	770	839	833	972	991	1,148	1,235	1,645	1,668	1,277	1,088
Back Bay-Mass Ave	691	712	736	747	895	899	1,064	1,125	1,557	1,502	1,185	990
Mass Ave-Ruggles	673	689	705	723	868	883	1,044	1,085	1,485	1,416	1,127	918
Ruggles-Roxbury Crossing	583	626	627	663	773	801	973	972	1,342	1,248	1,025	883
Roxbury Crossing-Jackson Sq	594	574	612	620	732	739	927	911	1,237	1,136	948	798
Jackson Sq-Stony Brook	493	476	509	510	612	610	788	774	1,056	972	820	683
Stony Brook-Green St	431	417	448	443	528	530	663	660	885	813	676	562
Green St-Forest Hills	384	360	392	379	450	442	570	537	699	647	548	437

Passengers by Route Segment and Time Period
Green Line Westbound - AM
Base Year

Route Segment (Branches)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM
Lechmere-Science Park (E)	39 27 60 54 52 86 112 108 171 160 165 163
Science Park-North Station (E)	38 29 58 54 54 88 118 112 179 167 169 164
North Station-Haymarket (C,E)	81 138 180 164 266 319 363 432 658 563 668 445
Haymarket-Gov Ctr (C,E)	124 216 256 249 356 437 440 502 764 647 790 513
Gov Ctr-Park St (B,C,D,E)	394 516 617 622 786 990 917 863 1,113 1,103 1,277 817
Park St-Boylston (B,C,D,E)	380 488 688 816 995 1,312 1,311 1,266 1,534 1,549 1,687 1,295
Boylston-Arlington (B,C,D,E)	368 470 665 785 973 1,277 1,273 1,217 1,484 1,474 1,594 1,225
Arlington-Copley (B,C,D,E)	326 411 565 703 872 1,120 1,086 995 1,193 1,198 1,265 976
Copley-Hynes (B,C,D)	207 270 354 466 587 718 712 678 716 723 735 539
Hynes-Kenmore (B,C,D)	199 248 340 444 556 673 664 623 647 653 608 464
Copley-Prudential (E)	85 106 148 215 251 321 318 282 372 344 361 286
Prudential-Symphony (E)	73 96 133 196 231 276 267 231 290 278 274 235

Passengers by Route Segment and Time Period
Green Line Eastbound - PM
Base Year

Route Segment (Branches)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Science Park-Lechmere (E)	139	132	138	119	125	151	130	138	195	181	168	144
North Station-Science Park (E)	145	140	146	126	127	161	139	148	204	195	179	153
Haymarket-North Station (C,E)	226	265	279	276	286	347	354	413	498	457	390	354
Gov Ctr-Haymarket (C,E)	300	344	374	354	368	431	456	503	600	576	498	454
Park St-Gov Ctr (B,C,D,E)	639	793	807	772	753	862	958	885	1,058	996	943	829
Bolyston-Park St (B,C,D,E)	946	1,124	1,064	1,094	1,146	1,230	1,399	1,365	1,671	1,581	1,526	1,463
Arlington-Bolyston (B,C,D,E)	966	1,136	1,098	1,093	1,134	1,222	1,396	1,335	1,637	1,587	1,571	1,503
Copley-Arlington (B,C,D,E)	921	1,083	1,072	1,105	1,037	1,122	1,254	1,172	1,378	1,411	1,483	1,430
Hynes-Copley (B,C,D)	500	593	619	668	651	653	752	748	786	786	958	740
Kenmore-Hynes (B,C,D)	481	561	598	638	624	599	714	705	702	732	920	695
Prudential-Copley (E)	408	444	422	432	336	443	463	410	479	526	459	638
Symphony-Prudential (E)	385	402	373	402	291	390	419	352	398	446	378	573

Passengers by Route Segment and Time Period
Green Line Eastbound - AM
Base Year

Route Segment (Branches)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM
Science Park-Lechmere (E)	32 38 54 62 64 107 117 110 127 145 158 123
North Station-Science Park (E)	40 42 66 69 72 118 141 135 151 176 193 139
Haymarket-North Station (C,E)	53 74 88 87 123 156 204 202 215 252 273 212
Gov Ctr-Haymarket (C,E)	57 81 96 103 140 176 241 234 251 300 341 283
Park St-Gov Ctr (B,C,D,E)	102 169 196 258 327 391 525 541 719 797 812 691
Bolyston-Park St (B,C,D,E)	109 182 215 304 475 598 833 853 1,204 1,353 1,401 1,124
Arlington-Bolyston (B,C,D,E)	128 200 240 332 502 644 918 947 1,313 1,481 1,530 1,265
Copley-Arlington (B,C,D,E)	135 216 261 368 552 720 1,035 1,069 1,452 1,632 1,704 1,446
Hynes-Copley (B,C,D)	107 167 230 331 497 579 916 872 1,280 1,476 1,495 1,241
Kenmore-Hynes (B,C,D)	106 163 224 316 492 582 909 861 1,298 1,495 1,494 1,270
Prudential-Copley (E)	29 57 47 53 89 168 204 262 266 289 320 289
Symphony-Prudential (E)	25 54 44 48 70 151 177 224 212 246 271 249

Passengers by Route Segment and Time Period
Green Line Westbound - PM
Base Year

Route Segment (Branches)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Lechmere-Science Park (E)	85	102	114	108	116	156	126	135	143	203	192	162
Science Park-North Station (E)	98	117	133	125	136	182	148	158	169	242	212	203
North Station-Haymarket (C,E)	173	181	189	179	244	226	207	230	282	393	297	298
Haymarket-Gov Ctr (C,E)	228	230	255	223	296	276	263	282	342	443	352	344
Gov Ctr-Park St (B,C,D,E)	496	522	556	521	640	626	640	653	1,000	972	817	715
Park St-Boylston (B,C,D,E)	641	722	782	786	798	853	873	982	1,446	1,544	1,373	1,164
Boylston-Arlington (B,C,D,E)	680	750	812	843	869	902	932	1,065	1,571	1,628	1,459	1,284
Arlington-Copley (B,C,D,E)	712	782	868	929	928	941	1,042	1,170	1,761	1,739	1,577	1,425
Copley-Hynes (B,C,D)	546	570	656	700	687	745	850	958	1,488	1,442	1,332	1,232
Hynes-Kenmore (B,C,D)	521	532	598	686	687	724	831	949	1,467	1,397	1,301	1,235
Copley-Prudential (E)	161	187	186	197	229	212	214	256	357	345	307	286
Prudential-Symphony (E)	128	151	157	169	201	167	176	209	309	280	251	235

Passengers by Route Segment and Time Period
Blue Line Southbound - AM
Base Year

Route Segment	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM
Wonderland-Revere Beach	66 133 164 150 180 291 283 298 293 349 363 274
Revere Beach-Beachmont	108 196 234 234 267 401 392 391 390 466 467 375
Beachmont-Suffolk Downs	154 250 326 316 372 507 494 532 512 620 610 512
Suffolk Downs-Orient Heights	162 261 338 333 393 530 518 558 539 645 643 546
Orient Heights-Wood Island	227 368 434 453 534 676 658 723 698 808 865 690
Wood Island-Airport	273 411 495 503 597 750 732 775 772 871 936 742
Airport-Maverick	345 531 613 642 730 900 873 908 903 1,016 1,100 882
Maverick-Aquarium	587 722 881 930 965 1,235 1,187 1,195 1,163 1,333 1,416 1,096
Aquarium-State	549 683 833 862 906 1,152 1,083 1,070 1,049 1,193 1,272 957
State-Govt Ctr	337 385 514 504 591 745 716 651 626 737 808 578
Gov Ctr-Bowdoin	29 39 75 63 78 73 105 102 96 97 90 63

Passengers by Route Segment and Time Period
Blue Line Northbound - PM
Base Year

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Revere Beach-Wonderland	111	137	153	161	226	204	256	304	386	322	279	230
Beachmont-Revere Beach	179	223	239	243	320	304	352	397	494	409	362	298
Suffolk Downs-Beachmont	247	299	317	323	422	396	464	518	663	538	476	379
Orient Heights-Suffolk Downs	266	316	339	335	447	417	484	532	705	565	496	396
Wood Island-Orient Heights	355	413	457	439	579	528	616	668	925	701	635	504
Airport-Wood Island	391	470	512	488	644	578	673	721	993	757	689	547
Maverick-Airport	501	602	642	608	760	726	826	843	1,147	890	801	632
Aquarium-Maverick	721	881	872	845	1,011	982	1,075	1,067	1,401	1,160	1,023	824
State-Aquarium	674	849	835	818	932	909	1,016	970	1,259	1,052	923	765
Gov Ctr-State	469	552	570	547	571	610	656	611	753	635	603	489
Bowdoin- Gov Ctr	51	55	68	69	95	87	83	96	132	103	61	53

Passengers by Route Segment and Time Period
Blue Line Northbound - AM
Base Year

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Revere Beach-Wonderland	13	22	16	16	26	23	21	17	15	21	15	18
Beachmont-Revere Beach	22	35	24	24	38	32	33	26	25	31	28	27
Suffolk Downs-Beachmont	30	41	33	28	43	38	35	26	30	37	33	30
Orient Heights-Suffolk Downs	32	42	34	30	44	39	39	27	34	44	33	31
Wood Island-Orient Heights	36	44	40	40	53	51	48	31	42	53	41	41
Airport-Wood Island	43	61	49	60	62	64	57	38	46	62	48	44
Maverick-Airport	63	103	111	129	129	113	87	58	84	94	70	60
Aquarium-Maverick	84	127	153	182	180	168	136	106	123	147	108	107
State-Aquarium	88	120	158	180	194	179	164	132	147	180	152	134
Gov Ctr-State	54	63	70	89	90	100	101	80	119	128	111	101
Bowdoin- Gov Ctr	0	0	1	3	2	4	2	4	5	7	6	10

Passengers by Route Segment and Time Period
Blue Line Southbound - PM
Base Year

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Wonderland-Revere Beach	41	55	61	48	51	65	32	49	50	52	26	54
Revere Beach-Beachmont	85	105	108	84	83	111	70	85	93	97	67	74
Beachmont-Suffolk Downs	110	129	139	112	109	142	94	103	121	119	96	94
Suffolk Downs-Orient Heights	120	139	145	117	120	152	105	111	146	131	109	105
Orient Heights-Wood Island	149	176	188	159	153	202	142	152	171	164	139	126
Wood Island-Airport	160	199	203	183	165	242	173	185	202	186	159	137
Airport-Maverick	241	297	301	280	241	330	254	289	315	297	252	204
Maverick-Aquarium	364	425	443	391	370	412	385	422	418	445	340	264
Aquarium-State	361	404	425	373	358	415	390	415	435	437	331	273
State-Govt Ctr	249	280	296	264	256	277	248	254	273	272	222	171
Gov Ctr-Bowdoin	8	10	11	11	6	5	6	5	9	9	4	4

Appendix F

Passengers per Vehicle in the Base Year

Appendix F shows the passengers per vehicle that were used for the Base Year in Figures 7 through 22.

The route segments and time periods with crowding are highlighted and indicate the crowding icon that is used in Figures 7 through 22.

Indicates "Overburdened" Icon



Indicates "Overcrowded" Icon



Indicates "Unacceptable" Icon



**Figure 7 Passengers per Vehicle
Red Line Southbound - AM
Base Year**

Route Segment (Branch)	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Alewife-Davis	3	8	7	16	13	19	24	30	27	29	35	32
Davis-Porter	8	13	13	29	26	36	44	59	56	61	78	72
Porter-Harvard	10	17	16	42	31	44	61	82	76	80	112	91
Harvard-Central	15	22	22	47	38	55	72	90	85	96	127	104
Central-Kendall	17	29	25	52	43	61	77	98	97	112	141	121
Kendall-Charles/MGH	16	29	24	47	42	59	72	88	89	102	124	107
Charles/MGH-Park St	14	24	18	38	38	53	65	78	82	94	113	98
Park St-Downtown Crossing	15	27	18	38	42	50	56	63	68	75	89	71
Downtown Crossing-South Station	18	37	23	45	54	57	57	59	63	68	77	61
South Station-Broadway	13	26	17	32	41	39	31	27	26	26	28	26
Broadway-Andrew	12	24	15	31	39	38	29	25	24	24	26	24
Andrew-JFK/UMASS	11	21	14	30	38	36	29	24	22	23	25	23
JFK/UMASS-N Quincy (Braintree)	8	16	12	17	34	24	20	23	22	18	15	15
N Quincy-Wollaston (Braintree)	7	14	9	14	27	16	14	15	15	11	11	11
Wollaston-Quincy Ctr (Braintree)	7	13	9	14	29	14	12	14	14	11	10	12
Quincy Ctr-Quincy Adams (Braintree)	5	9	5	6	10	6	5	7	6	4	4	4
Quincy Adams-Braintree (Braintree)	3	5	3	3	6	3	2	2	3	1	1	2
JFK/UMASS-Savin Hill (Ashmont)	8	11	11	20	14	11	9	11	9	8	8	7
Savin Hill-Fields Corner (Ashmont)	8	10	10	14	11	10	9	10	8	7	7	7
Fields Corner-Shawmut (Ashmont)	8	8	10	15	10	8	6	8	7	5	5	6
Shawmut-Ashmont (Ashmont)	7	7	10	14	9	7	5	6	5	4	4	5

Figure 8 Passengers per Vehicle
Red Line Northbound - PM
Base Year

Route Segment (Branch)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Davis-Alewife	12	10	10	17	16	18	26	22	30	33	26	21
Porter-Davis	23	19	20	31	28	32	45	41	61	70	57	47
Harvard-Porter	31	25	27	39	37	49	58	56	85	94	76	63
Central-Harvard	42	35	37	54	47	62	76	69	106	122	98	78
Kendall-Central	48	39	42	61	52	65	83	73	116	138	115	89
Charles/MGH-Kendall	48	39	40	58	48	56	77	62	104	127	106	81
Park St-Charles/MGH	50	39	38	56	45	52	70	57	94	118	99	76
Downtown Crossing-Park St	46	38	37	53	37	47	59	49	73	101	86	61
South Station-Downtown Crossing	52	44	44	63	38	48	62	52	66	97	87	58
Broadway-South Station	42	36	36	50	25	33	37	31	31	46	44	28
Andrew-Broadway	40	35	34	47	24	31	35	29	28	42	41	26
JFK/UMASS-Andrew	38	33	31	43	22	28	33	27	26	38	38	25
N Quincy-JFK/UMASS (Braintree)	32	22	23	34	19	24	33	26	22	46	32	25
Wollaston-N Quincy (Braintree)	27	19	19	28	15	19	26	20	18	28	21	20
Quincy Ctr-Wollaston (Braintree)	26	17	17	25	14	16	24	18	16	24	20	18
Quincy Adams-Quincy Ctr (Braintree)	10	6	9	13	7	8	13	11	9	12	10	11
Braintree-Quincy Adams (Braintree)	7	4	5	7	5	6	8	5	5	5	6	4
Savin Hill-JFK/UMASS (Ashmont)	29	28	22	28	15	19	21	16	19	17	20	12
Fields Corner-Savin Hill (Ashmont)	27	24	17	25	13	16	18	14	18	15	17	10
Shawmut-Fields Corner (Ashmont)	24	24	12	17	10	11	14	10	12	10	11	8
Ashmont-Shawmut (Ashmont)	22	22	9	14	8	9	12	8	10	8	8	6

Figure 9 Passengers per Vehicle
Red Line Northbound - AM
Base Year

Route Segment (Branch)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM																
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM					
Davis-Alewife	5	7	6	6	7	7	7	9	9	8	5	5					
Porter-Davis	6	7	7	8	11	10	9	12	12	12	9	9					
Harvard-Porter	6	9	9	10	14	12	12	15	14	15	12	11					
Central-Harvard	12	19	16	20	26	25	26	34	33	37	35	27					
Kendall-Central	14	24	20	26	34	31	32	42	42	44	45	31					
Charles/MGH-Kendall	17	31	28	35	43	42	46	63	62	68	66	50					
Park St-Charles/MGH	26	49	45	49	56	52	59	77	72	76	74	57					
Downtown Crossing-Park St	28	52	53	65	74	68	77	103	100	101	97	84					
South Station-Downtown Crossing	31	60	62	77	85	79	88	124	123	118	115	107					
Broadway-South Station	36	56	62	75	86	81	94	128	130	123	126	124					
Andrew-Broadway	35	54	61	75	84	79	91	125	124	116	118	118					
JFK/UMASS-Andrew	33	51	58	74	81	77	88	119	119	110	113	112					
N Quincy-JFK/UMASS (Braintree)	44	109	66	120	119	106	160	136	156	163	163	145					
Wollaston-N Quincy (Braintree)	36	89	55	99	98	86	133	113	125	130	129	110					
Quincy Ctr-Wollaston (Braintree)	27	73	43	78	79	68	106	89	99	99	102	88					
Quincy Adams-Quincy Ctr (Braintree)	18	45	29	51	49	43	67	56	63	54	54	50					
Braintree-Quincy Adams (Braintree)	12	29	20	31	31	28	42	37	36	26	19	21					
Savin Hill-JFK/UMASS (Ashmont)	47	46	52	81	68	94	71	100	71	70	90	84					
Fields Corner-Savin Hill (Ashmont)	45	40	47	74	64	90	67	90	60	59	79	73					
Shawmut-Fields Corner (Ashmont)	32	29	32	54	48	69	52	67	50	47	65	59					
Ashmont-Shawmut (Ashmont)	27	19	25	43	37	56	40	54	38	36	51	46					

**Figure 10 Passengers per Vehicle
Red Line Southbound - PM
Base Year**

Route Segment (Branch)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Alewife-Davis	6	7	6	6	6	7	8	6	8	9	9	9
Davis-Porter	15	15	12	11	13	12	14	11	13	15	15	15
Porter-Harvard	18	20	16	15	17	15	17	15	18	20	18	18
Harvard-Central	36	45	38	33	35	37	35	27	39	44	35	34
Central-Kendall	43	51	46	38	44	44	43	33	50	53	42	41
Kendall-Charles/MGH	51	59	55	44	61	55	58	45	74	75	56	54
Charles/MGH-Park St	60	67	73	52	76	64	74	53	89	82	63	60
Park St-Downtown Crossing	74	80	82	65	101	76	94	69	120	98	74	72
Downtown Crossing-South Station	82	90	89	72	112	85	107	81	140	110	84	80
South Station-Broadway	82	88	85	71	112	88	106	86	159	112	92	85
Broadway-Andrew	82	86	84	69	112	86	104	85	155	109	89	83
Andrew-JFK/UMASS	78	82	81	67	110	84	101	83	148	105	85	79
JFK/UMASS-N Quincy (Braintree)	89	94	76	85	151	128	113	104	149	135	103	91
N Quincy-Wollaston (Braintree)	75	79	65	71	124	105	90	85	122	110	82	72
Wollaston-Quincy Ctr (Braintree)	63	65	54	57	99	88	72	68	98	87	65	59
Quincy Ctr-Quincy Adams (Braintree)	36	37	34	35	60	52	43	39	57	47	37	32
Quincy Adams-Braintree (Braintree)	21	21	20	21	36	30	25	21	28	23	17	14
JFK/UMASS-Savin Hill (Ashmont)	67	64	80	50	71	48	77	54	132	66	57	56
Savin Hill-Fields Corner (Ashmont)	66	60	73	46	64	44	69	49	117	59	51	47
Fields Corner-Shawmut (Ashmont)	50	43	58	35	47	35	52	40	89	46	40	37
Shawmut-Ashmont (Ashmont)	41	35	46	28	36	26	40	31	69	36	32	29

**Figure 11 Passengers per Vehicle
Orange Line Southbound - AM
Base Year**

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Oak Grove-Malden Ctr	17	15	20	16	28	22	32	25	23	31	29	28
Malden Ctr-Wellington	39	42	41	42	62	52	72	57	61	81	80	83
Wellington-Assembly	52	54	58	57	79	65	92	74	80	104	105	112
Assembly-Sullivan Sq	52	54	58	57	79	65	92	74	80	104	105	112
Sullivan Sq-Community College	76	73	71	72	94	74	107	92	97	124	124	132
Community College-North Station	77	75	71	71	93	76	108	93	96	122	126	134
North Station-Haymarket	64	71	72	64	94	76	110	101	112	121	137	134
Haymarket-State	69	81	78	69	99	79	111	102	114	122	139	133
State-Downtown Crossing	78	92	89	76	102	81	107	95	104	109	124	117
Downtown Crossing-Chinatown	71	78	82	70	87	74	94	85	90	95	109	107
Chinatown-Tufts Medical Ctr	64	73	76	64	81	69	86	77	81	85	97	94
Tufts Medical Ctr-Back Bay	57	64	65	55	70	60	73	66	68	72	84	81
Back Bay-Mass Ave	38	44	47	38	44	35	42	31	32	34	36	38
Mass Ave-Ruggles	36	42	44	36	41	32	37	28	28	30	30	31
Ruggles-Roxbury Crossing	22	27	28	23	24	17	16	14	13	14	15	14
Roxbury Crossing-Jackson Sq	19	22	24	19	18	13	14	12	11	12	12	11
Jackson Sq-Stony Brook	22	22	24	18	15	10	12	10	9	10	9	9
Stony Brook-Green St	24	22	24	18	15	10	11	10	8	9	7	8
Green St-Forest Hills	24	21	23	16	13	7	8	7	6	7	6	7

**Figure 12 Passengers per Vehicle
Orange Line Northbound - PM
Base Year**

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Malden Ctr-Oak Grove	9	10	11	14	19	16	20	22	30	28	22	20
Wellington-Malden Ctr	29	27	29	38	44	39	48	52	77	69	61	54
Assembly-Wellington	39	37	40	51	58	50	64	65	100	89	81	70
Sullivan Sq-Assembly	39	37	40	51	58	50	64	65	100	89	81	70
Community College-Sullivan Sq	52	48	51	64	72	62	77	78	119	109	98	84
North Station-Community College	57	54	55	65	73	64	80	81	121	115	107	89
Haymarket-North Station	53	51	54	67	76	65	79	88	130	118	104	89
State-Haymarket	55	54	56	70	77	66	81	89	130	120	107	92
Downtown Crossing-State	60	62	63	76	80	66	80	84	120	116	101	90
Chinatown-Downtown Crossing	61	65	59	72	76	62	75	77	108	109	92	84
Tufts Medical Ctr-Chinatown	56	61	56	67	67	56	70	71	97	103	87	78
Back Bay-Tufts Medical Ctr	52	57	50	60	59	50	61	63	85	92	79	70
Mass Ave-Back Bay	40	48	41	50	43	35	41	43	47	53	47	42
Ruggles-Mass Ave	37	46	40	47	39	32	37	39	43	47	42	37
Roxbury Crossing-Ruggles	24	33	29	31	26	21	21	22	27	27	26	22
Jackson Sq-Roxbury Crossing	22	24	25	26	23	18	19	19	23	23	22	21
Stony Brook-Jackson Sq	19	22	23	22	20	14	15	15	19	17	18	17
Green St-Stony Brook	16	19	21	19	18	13	14	13	17	14	15	15
Forest Hills-Green St	15	18	16	13	15	11	11	11	14	12	12	11

**Figure 13 Passengers per Vehicle
Orange Line Northbound - AM
Base Year**

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Malden Ctr-Oak Grove	2	2	1	2	1	1	1	1	1	1	1	1
Wellington-Malden Ctr	5	6	5	8	5	5	5	7	9	6	6	5
Assembly-Wellington	9	10	9	12	8	9	9	12	15	10	10	8
Sullivan Sq-Assembly	9	10	9	12	8	9	9	12	15	10	10	8
Community College-Sullivan Sq	16	18	19	22	16	16	17	19	23	17	16	13
North Station-Community College	18	25	31	33	20	20	25	31	41	26	23	19
Haymarket-North Station	24	31	41	42	28	28	36	42	51	40	37	33
State-Haymarket	26	33	44	47	31	31	42	50	58	48	46	44
Downtown Crossing-State	28	34	51	54	38	38	53	64	79	71	73	70
Chinatown-Downtown Crossing	33	36	57	65	48	52	65	76	92	90	99	93
Tufts Medical Ctr-Chinatown	33	36	57	65	48	53	67	79	94	93	104	97
Back Bay-Tufts Medical Ctr	34	39	59	65	47	55	71	83	101	100	108	101
Mass Ave-Back Bay	37	37	54	65	45	57	67	79	91	84	103	87
Ruggles-Mass Ave	37	36	51	63	44	54	64	75	87	79	98	84
Roxbury Crossing-Ruggles	36	29	48	59	44	56	61	73	84	76	94	81
Jackson Sq-Roxbury Crossing	35	28	46	58	45	56	60	70	79	70	89	75
Stony Brook-Jackson Sq	29	24	36	48	36	48	50	58	66	60	78	63
Green St-Stony Brook	26	20	32	44	32	43	44	50	56	51	64	49
Forest Hills-Green St	23	18	29	39	29	39	38	42	45	41	52	37

**Figure 14 Passengers per Vehicle
Orange Line Southbound - PM
Base Year**

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Oak Grove-Malden Ctr	3	3	3	4	4	2	2	2	3	2	2	2
Malden Ctr-Wellington	11	15	15	13	13	10	10	11	11	12	9	10
Wellington-Assembly	15	21	22	19	18	16	14	17	18	19	15	14
Assembly-Sullivan Sq	15	21	22	19	18	16	14	17	18	19	15	14
Sullivan Sq-Community College	26	32	36	29	28	26	22	27	27	29	22	21
Community College-North Station	30	37	40	42	40	31	26	31	33	45	28	24
North Station-Haymarket	32	41	46	46	48	35	34	41	43	55	35	31
Haymarket-State	37	46	52	50	57	40	39	49	53	61	40	34
State-Downtown Crossing	46	53	61	55	69	48	51	63	78	76	54	46
Downtown Crossing-Chinatown	58	68	79	66	80	58	64	77	97	96	73	63
Chinatown-Tufts Medical Ctr	58	66	77	65	80	57	64	78	98	96	73	65
Tufts Medical Ctr-Back Bay	58	66	77	65	83	59	65	80	101	97	73	66
Back Bay-Mass Ave	56	61	68	58	76	53	60	73	96	88	68	60
Mass Ave-Ruggles	55	59	65	56	74	52	59	70	91	83	65	55
Ruggles-Roxbury Crossing	47	53	58	52	66	48	55	63	82	73	59	53
Roxbury Crossing-Jackson Sq	48	49	56	48	62	44	52	59	76	66	54	48
Jackson Sq-Stony Brook	40	41	47	40	52	36	44	50	65	57	47	41
Stony Brook-Green St	35	36	41	34	45	31	37	43	54	47	39	34
Green St-Forest Hills	31	31	36	29	38	26	32	35	43	38	31	26

Route Segment (Branches)													
Lechmere-Science Park (E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	11	8	16	14	11	17	23	23	35	36	33	36	36
Science Park-North Station (E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	10	9	16	14	11	18	24	23	37	38	33	36	36
North Station-Haymarket (C,E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	11	22	25	20	27	32	37	45	67	64	66	49	49
Haymarket-Gov Ctr (C,E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	17	34	35	31	36	44	45	52	78	73	78	56	56
Gov Ctr-Park St (B,C,D,E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	29	44	46	42	41	51	48	46	57	63	64	45	45
Park St-Boylston (B,C,D,E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	28	42	51	55	52	68	68	68	79	88	84	71	71
Boylston-Arlington (B,C,D,E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	27	40	49	53	51	66	66	65	77	84	79	68	68
Arlington-Copley (B,C,D,E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	24	35	42	47	45	58	57	53	62	68	63	54	54
Copley-Hynes (B,C,D)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	19	25	36	44	46	56	52	50	59	75	53	35	35
Hynes-Kenmore (B,C,D)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	18	23	34	42	44	53	48	46	53	68	44	30	30
Copley-Prudential (E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	23	34	41	54	51	65	65	59	76	78	71	63	63
Prudential-Symphony (E)	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
	20	30	36	49	47	56	54	48	59	63	54	51	51

**Figure 16 Passengers per Vehicle
Green Line Northbound - PM
Base Year**

Route Segment (Branches)	3:00PM - 3:15PM - 3:30PM - 3:45PM - 4:00PM - 4:15PM - 4:30PM - 4:45PM - 5:00PM - 5:15PM - 5:30PM - 5:45PM - 6:00PM													
	3:15PM	3:30PM	3:45PM	4:00PM	4:15PM	4:30PM	4:45PM	5:00PM	5:15PM	5:30PM	5:45PM	6:00PM		
Science Park-Lechmere (E)	34	32	32	28	25	35	27	29	47	34	36	34		
North Station-Science Park (E)	35	34	34	30	26	37	29	31	49	36	39	36		
Haymarket-North Station (C,E)	28	32	33	33	29	40	37	43	60	43	42	41		
Gov Ctr-Haymarket (C,E)	36	41	44	42	37	50	48	52	72	54	53	53		
Park St-Gov Ctr (B,C,D,E)	42	51	51	49	41	53	54	49	64	47	51	49		
Bolyston-Park St (B,C,D,E)	62	73	67	70	62	76	78	75	102	75	83	86		
Arlington-Bolyston (B,C,D,E)	63	74	69	70	61	75	78	74	100	75	85	88		
Copley-Arlington (B,C,D,E)	60	70	68	71	56	69	70	65	84	67	80	84		
Hynes-Copley (B,C,D)	45	53	54	59	48	55	57	56	67	52	72	61		
Kenmore-Hynes (B,C,D)	43	50	52	56	46	50	54	53	60	48	70	57		
Prudential-Copley (E)	99	107	99	103	68	102	97	85	116	98	99	148		
Symphony-Prudential (E)	94	97	87	95	59	90	88	73	96	83	81	133		

**Figure 17 Passengers per Vehicle
Green Line Northbound - AM
Base Year**

Route Segment (Branches)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM											
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM
Science Park-Lechmere (E)	9	11	11	13	12	20	27	19	26	31	32	23
North Station-Science Park (E)	12	12	13	14	13	22	32	23	30	38	39	26
Haymarket-North Station (C,E)	8	11	9	9	11	15	23	17	22	27	28	20
Gov Ctr-Haymarket (C,E)	8	12	9	11	13	17	27	20	25	32	34	26
Park St-Gov Ctr (B,C,D,E)	8	13	10	14	15	19	30	23	37	44	42	33
Bolyston-Park St (B,C,D,E)	9	14	11	17	22	28	48	37	62	74	72	53
Arlington-Bolyston (B,C,D,E)	10	16	13	18	24	31	53	41	67	81	79	60
Copley-Arlington (B,C,D,E)	11	17	14	20	26	34	60	46	75	89	87	69
Hynes-Copley (B,C,D)	11	18	17	25	32	37	71	50	88	108	103	79
Kenmore-Hynes (B,C,D)	11	18	16	24	31	37	70	50	89	110	103	81
Prudential-Copley (E)	8	17	9	11	17	31	46	45	54	62	64	54
Symphony-Prudential (E)	7	16	9	10	13	28	40	38	43	53	55	46

**Figure 18 Passengers per Vehicle
Green Line Southbound - PM
Base Year**

Route Segment (Branches)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Lechmere-Science Park (E)	21	25	31	28	25	33	25	27	34	62	41	31
Science Park-North Station (E)	25	29	36	32	29	39	29	31	40	74	45	38
North Station-Haymarket (C,E)	22	23	26	23	26	24	20	23	34	60	32	28
Haymarket-Gov Ctr (C,E)	28	29	35	28	31	29	26	28	41	67	37	32
Gov Ctr-Park St (B,C,D,E)	33	35	41	36	37	36	34	35	61	75	44	34
Park St-Boylston (B,C,D,E)	43	49	57	54	46	49	46	53	88	120	74	56
Boylston-Arlington (B,C,D,E)	46	50	60	58	50	52	49	57	96	126	79	62
Arlington-Copley (B,C,D,E)	48	53	64	64	53	54	55	63	108	135	85	69
Copley-Hynes (B,C,D)	50	53	66	66	54	59	62	70	122	150	97	80
Hynes-Kenmore (B,C,D)	48	49	60	64	54	57	60	70	121	145	95	80
Copley-Prudential (E)	40	47	50	50	49	45	42	51	86	105	65	54
Prudential-Symphony (E)	32	38	43	43	43	35	35	41	74	85	53	44

Figure 19 Passengers per Vehicle
Blue Line Southbound - AM
Base Year

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Wonderland-Revere Beach	5	10	14	8	9	17	13	15	16	18	17	16
Revere Beach-Beachmont	8	15	20	12	13	23	18	20	21	24	22	22
Beachmont-Suffolk Downs	12	19	29	17	18	29	22	27	27	32	28	30
Suffolk Downs-Orient Heights	13	20	30	17	19	30	24	28	29	34	30	32
Orient Heights-Wood Island	18	28	38	24	25	39	30	37	37	42	40	41
Wood Island-Airport	21	31	43	26	28	43	33	39	41	46	44	44
Airport-Maverick	27	40	54	34	35	52	40	46	48	53	51	52
Maverick-Aquarium	46	55	77	49	46	71	54	61	62	70	66	65
Aquarium-State	43	52	73	45	43	66	49	54	56	62	59	57
State-Govt Ctr	26	29	45	26	28	43	33	33	33	39	38	34
Gov Ctr-Bowdoin	2	3	7	3	4	4	5	5	5	5	4	4

Figure 20 Passengers per Vehicle
Blue Line Northbound - PM
Base Year

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Revere Beach-Wonderland	6	7	7	9	12	10	12	17	21	15	14	13
Beachmont-Revere Beach	9	12	11	13	17	15	17	22	27	19	18	16
Suffolk Downs-Beachmont	12	16	15	17	22	20	23	28	36	25	24	21
Orient Heights-Suffolk Downs	13	17	16	18	24	21	24	29	39	26	25	22
Wood Island-Orient Heights	18	22	22	23	31	27	30	37	51	33	32	28
Airport-Wood Island	20	25	25	26	34	29	33	39	54	35	35	30
Maverick-Airport	25	32	31	32	40	37	40	46	63	42	41	35
Aquarium-Maverick	36	47	42	45	54	50	52	58	77	54	52	45
State-Aquarium	34	45	40	43	49	46	49	53	69	49	47	42
Gov Ctr-State	23	29	27	29	30	31	32	33	41	30	31	27
Bowdoin- Gov Ctr	3	3	3	4	5	4	4	5	7	5	3	3

[illegible]

Figure 22 Passengers per Vehicle
Blue Line Southbound - PM
Base Year

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Wonderland-Revere Beach	2	3	3	2	3	3	2	3	3	2	1	3
Revere Beach-Beachmont	4	6	5	4	4	6	3	5	5	5	3	4
Beachmont-Suffolk Downs	6	7	7	6	6	7	5	6	7	6	5	5
Suffolk Downs-Orient Heights	6	7	7	6	6	8	5	6	8	6	6	6
Orient Heights-Wood Island	8	9	9	8	8	10	7	8	9	8	7	7
Wood Island-Airport	8	11	10	10	9	12	9	10	11	9	8	7
Airport-Maverick	12	16	15	15	13	17	13	16	17	14	13	11
Maverick-Aquarium	18	23	22	20	20	21	19	23	23	21	17	14
Aquarium-State	18	21	21	19	19	21	19	22	24	21	17	15
State-Govt Ctr	13	15	14	14	14	14	12	14	15	13	11	9
Gov Ctr-Bowdoin	0	1	1	1	0	0	0	0	1	0	0	0

Appendix G

Passengers per Vehicle in the 2040 No- Build Scenario

Appendix F shows the passengers per vehicle that were used for the 2040 No-Build Scenario in Figures 7 through 22.

The route segments and time periods with crowding are highlighted and indicate the crowding icon that is used in Figures 7 through 22.

Indicates "Overburdened" Icon



Indicates "Overcrowded" Icon



Indicates "Unacceptable" Icon



**Figure 7 Passengers per Vehicle
Red Line Southbound - AM
2040 No Build**

Route Segment (Branch)	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Alewife-Davis	4	8	7	17	14	20	25	32	29	31	38	34
Davis-Porter	8	14	14	32	28	39	48	64	61	66	84	78
Porter-Harvard	11	18	17	45	34	47	66	88	82	86	120	98
Harvard-Central	16	24	24	52	42	60	79	99	93	105	140	114
Central-Kendall	19	33	28	59	49	70	88	112	110	127	161	137
Kendall-Charles/MGH	19	33	27	54	47	67	82	100	101	116	141	121
Charles/MGH-Park St	16	28	21	44	44	61	75	90	94	108	130	113
Park St-Downtown Crossing	16	29	19	40	45	53	60	67	73	80	95	75
Downtown Crossing-South Station	18	37	23	45	55	58	58	60	64	69	78	62
South Station-Broadway	13	27	17	33	42	40	32	28	27	27	29	27
Broadway-Andrew	13	25	16	32	41	39	30	26	25	25	27	25
Andrew-JFK/UMASS	11	21	15	31	39	37	29	24	23	24	26	24
JFK/UMASS-N Quincy (Braintree)	8	16	12	17	34	24	20	23	22	18	15	15
N Quincy-Wollaston (Braintree)	7	14	9	14	28	16	14	15	15	11	11	12
Wollaston-Quincy Ctr (Braintree)	7	14	9	15	29	15	13	14	14	11	10	12
Quincy Ctr-Quincy Adams (Braintree)	5	9	5	6	10	6	5	7	6	5	4	4
Quincy Adams-Braintree (Braintree)	3	5	3	3	6	3	2	2	3	1	1	2
JFK/UMASS-Savin Hill (Ashmont)	8	11	11	20	14	11	9	11	9	8	8	8
Savin Hill-Fields Corner (Ashmont)	8	10	11	15	11	10	9	11	8	7	7	7
Fields Corner-Shawmut (Ashmont)	8	8	11	15	10	8	6	8	7	5	5	6
Shawmut-Ashmont (Ashmont)	8	8	10	14	9	7	5	6	5	4	4	6

**Figure 8 Passengers per Vehicle
Red Line Northbound - PM
2040 No Build**

Route Segment (Branch)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Davis-Alewife	13	10	11	18	18	20	28	23	32	36	28	23
Porter-Davis	25	20	22	34	30	35	49	45	66	75	62	51
Harvard-Porter	33	26	29	42	40	53	62	60	91	100	82	67
Central-Harvard	47	39	41	59	52	68	84	76	116	134	107	86
Kendall-Central	55	45	47	69	59	74	95	82	132	156	131	101
Charles/MGH-Kendall	54	44	46	66	55	64	88	70	118	144	121	93
Park St-Charles/MGH	58	45	44	65	52	61	81	66	109	136	114	88
Downtown Crossing-Park St	49	40	39	57	40	50	63	53	79	108	93	65
South Station-Downtown Crossing	53	45	45	64	39	49	63	53	67	98	88	59
Broadway-South Station	44	38	37	52	26	34	39	32	32	48	46	29
Andrew-Broadway	43	37	36	49	25	33	37	31	30	44	43	28
JFK/UMASS-Andrew	39	34	32	44	23	29	35	28	27	39	39	26
N Quincy-JFK/UMASS (Braintree)	32	22	23	34	20	25	34	26	23	47	32	26
Wollaston-N Quincy (Braintree)	27	19	19	28	15	19	26	20	18	28	22	20
Quincy Ctr-Wollaston (Braintree)	27	17	17	25	14	17	24	19	16	25	20	19
Quincy Adams-Quincy Ctr (Braintree)	10	6	9	14	7	9	13	11	9	12	11	12
Braintree-Quincy Adams (Braintree)	7	4	5	7	5	6	8	5	5	6	6	4
Savin Hill-JFK/UMASS (Ashmont)	30	29	23	29	15	20	22	16	20	18	21	12
Fields Corner-Savin Hill (Ashmont)	39	34	32	44	23	29	35	28	27	39	39	26
Shawmut-Fields Corner (Ashmont)	43	37	36	49	25	33	37	31	30	44	43	28
Ashmont-Shawmut (Ashmont)	44	38	37	52	26	34	39	32	32	48	46	29

**Figure 9 Passengers per Vehicle
Red Line Northbound - AM
2040 No Build**

Route Segment (Branch)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM - 9:00AM															
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM				
Davis-Alewife	5	7	6	6	7	7	8	10	10	8	6	6				
Porter-Davis	6	7	7	8	11	10	10	12	12	12	9	9				
Harvard-Porter	6	9	9	11	14	12	12	16	15	15	12	12				
Central-Harvard	13	20	17	20	28	26	27	35	34	38	37	28				
Kendall-Central	15	25	21	28	36	33	35	45	44	47	48	34				
Charles/MGH-Kendall	19	34	31	38	48	46	51	69	68	75	73	56				
Park St-Charles/MGH	30	56	52	57	65	61	69	89	84	88	85	66				
Downtown Crossing-Park St	31	58	59	72	82	75	85	115	111	112	107	93				
South Station-Downtown Crossing	32	61	64	79	87	81	90	128	126	122	118	110				
Broadway-South Station	40	62	69	84	95	90	105	143	144	137	140	138				
Andrew-Broadway	41	63	71	87	98	92	106	146	145	135	138	137				
JFK/UMASS-Andrew	37	57	64	83	90	86	98	134	133	123	127	125				
N Quincy-JFK/UMASS (Braintree)	46	116	69	127	126	113	169	144	166	172	173	154				
Wollaston-N Quincy (Braintree)	38	94	58	104	103	91	140	120	132	137	137	116				
Quincy Ctr-Wollaston (Braintree)	30	80	47	85	86	74	116	97	109	108	111	96				
Quincy Adams-Quincy Ctr (Braintree)	20	49	31	56	53	47	74	61	69	59	60	55				
Braintree-Quincy Adams (Braintree)	13	33	23	35	35	32	48	42	40	29	21	23				
Savin Hill-JFK/UMASS (Ashmont)	53	51	58	92	77	106	80	113	80	79	102	95				
Fields Corner-Savin Hill (Ashmont)	50	44	52	82	72	100	74	100	67	66	88	81				
Shawmut-Fields Corner (Ashmont)	36	32	35	60	53	77	58	74	56	53	72	66				
Ashmont-Shawmut (Ashmont)	30	21	28	48	41	62	44	59	42	40	56	50				

Figure 10 Passengers per Vehicle
Red Line Southbound - PM
2040 No Build

Route Segment (Branch)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Alewife-Davis	7	7	7	6	6	7	7	8	8	9	9	9
Davis-Porter	15	16	13	12	13	12	15	12	14	15	15	15
Porter-Harvard	18	21	16	15	17	15	18	15	18	20	18	18
Harvard-Central	37	47	40	34	37	39	36	28	40	46	36	36
Central-Kendall	46	55	50	41	47	47	46	35	54	57	45	44
Kendall-Charles/MGH	56	65	61	48	67	61	64	50	81	82	62	60
Charles/MGH-Park St	69	77	85	60	88	74	86	61	103	95	73	69
Park St-Downtown Crossing	81	88	91	71	111	84	103	76	132	108	82	79
Downtown Crossing-South Station	84	92	91	73	114	87	109	83	144	112	86	81
South Station-Broadway	90	97	94	78	124	97	117	95	176	124	102	94
Broadway-Andrew	94	99	96	79	129	99	119	98	179	125	102	95
Andrew-JFK/UMASS	86	90	90	74	122	93	112	92	164	116	94	87
JFK/UMASS-N Quincy (Braintree)	93	99	80	89	159	135	119	110	157	142	108	96
N Quincy-Wollaston (Braintree)	79	83	69	75	131	111	95	90	128	116	86	76
Wollaston-Quincy Ctr (Braintree)	69	70	59	62	108	95	78	74	107	95	71	64
Quincy Ctr-Quincy Adams (Braintree)	39	40	37	38	66	56	47	43	62	52	40	35
Quincy Adams-Braintree (Braintree)	24	23	22	24	40	33	28	24	32	26	19	16
JFK/UMASS-Savin Hill (Ashmont)	74	71	89	56	79	54	86	60	146	74	64	62
Savin Hill-Fields Corner (Ashmont)	73	66	80	51	70	48	76	54	128	65	56	51
Fields Corner-Shawmut (Ashmont)	55	47	64	38	52	38	58	44	98	51	44	41
Shawmut-Ashmont (Ashmont)	45	38	50	30	39	29	43	33	76	39	35	31

**Figure 11 Passengers per Vehicle
Orange Line Southbound - AM
2040 No Build**

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Oak Grove-Malden Ctr	15	15	20	17	23	29	35	26	30	39	44	31
Malden Ctr-Wellington	32	37	37	41	48	63	71	54	72	93	110	83
Wellington-Assembly	40	45	50	54	58	74	87	66	90	114	137	106
Assembly-Sullivan Sq	46	51	57	62	66	85	99	75	103	131	157	122
Sullivan Sq-Community College	59	62	63	69	70	87	103	84	111	137	164	127
Community College-North Station	66	70	68	75	75	98	114	92	120	148	182	142
North Station-Haymarket	57	70	73	71	80	103	121	105	146	155	209	148
Haymarket-State	56	72	72	70	76	96	112	96	135	141	191	134
State-Downtown Crossing	55	70	70	65	68	85	92	77	106	108	147	101
Downtown Crossing-Chinatown	57	68	74	69	66	89	92	79	105	108	148	106
Chinatown-Tufts Medical Ctr	52	65	69	64	63	84	86	73	96	98	133	94
Tufts Medical Ctr-Back Bay	43	53	55	51	50	67	68	58	75	77	107	76
Back Bay-Mass Ave	29	37	41	36	33	41	40	28	37	37	47	36
Mass Ave-Ruggles	28	36	39	35	30	37	36	25	32	33	40	30
Ruggles-Roxbury Crossing	17	23	24	22	17	19	15	13	14	16	19	13
Roxbury Crossing-Jackson Sq	15	19	20	18	13	14	13	11	12	13	15	11
Jackson Sq-Stony Brook	17	19	21	17	11	12	11	9	10	11	12	9
Stony Brook-Green St	18	19	21	17	11	11	11	9	9	10	10	7
Green St-Forest Hills	18	18	19	15	9	8	8	6	7	8	7	6

**Figure 12 Passengers per Vehicle
Orange Line Northbound - PM
2040 No Build**

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Malden Ctr-Oak Grove	10	11	13	16	22	19	23	25	35	32	26	23
Wellington-Malden Ctr	31	29	31	40	47	42	51	55	82	74	65	57
Assembly-Wellington	40	37	41	52	59	51	65	66	102	91	82	71
Sullivan Sq-Assembly	55	51	56	72	82	71	89	91	141	125	113	98
Community College-Sullivan Sq	53	49	53	66	74	63	79	80	121	111	101	86
North Station-Community College	64	61	61	73	83	71	89	91	135	129	120	100
Haymarket-North Station	63	60	64	79	89	77	93	104	153	138	123	104
State-Haymarket	59	58	60	75	82	71	86	95	139	129	115	98
Downtown Crossing-State	56	58	58	71	74	62	74	78	111	108	94	83
Chinatown-Downtown Crossing	65	69	63	76	80	66	80	82	114	116	98	89
Tufts Medical Ctr-Chinatown	60	65	60	72	73	61	75	76	105	110	93	84
Back Bay-Tufts Medical Ctr	52	57	50	60	59	50	61	63	85	92	79	70
Mass Ave-Back Bay	41	50	42	51	44	36	42	44	48	54	48	43
Ruggles-Mass Ave	39	48	41	49	41	34	39	41	45	50	44	39
Roxbury Crossing-Ruggles	25	34	29	32	27	22	22	22	27	27	27	23
Jackson Sq-Roxbury Crossing	22	24	26	27	24	18	19	20	24	24	23	21
Stony Brook-Jackson Sq	19	23	24	23	21	15	16	16	20	18	19	17
Green St-Stony Brook	17	20	22	20	18	13	14	14	17	15	16	16
Forest Hills-Green St	15	18	16	13	16	11	11	11	14	12	13	12

**Figure 13 Passengers per Vehicle
Orange Line Northbound - AM
2040 No Build**

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Malden Ctr-Oak Grove	2	2	1	2	1	1	1	1	1	1	1	1
Wellington-Malden Ctr	5	6	5	8	5	5	5	7	9	6	6	5
Assembly-Wellington	9	10	9	12	8	9	9	12	15	10	10	8
Sullivan Sq-Assembly	13	14	13	17	12	13	13	17	22	14	14	11
Community College-Sullivan Sq	15	17	17	21	15	15	16	18	22	16	15	12
North Station-Community College	19	26	33	34	21	21	26	33	43	27	24	20
Haymarket-North Station	26	33	44	46	30	30	38	45	54	43	39	36
State-Haymarket	27	34	46	49	32	32	43	51	60	50	48	45
Downtown Crossing-State	26	32	49	51	36	37	50	61	75	67	70	67
Chinatown-Downtown Crossing	35	38	60	68	50	55	69	80	97	95	104	98
Tufts Medical Ctr-Chinatown	36	39	62	70	51	57	72	85	101	100	112	105
Back Bay-Tufts Medical Ctr	34	38	59	65	47	54	71	83	101	99	108	101
Mass Ave-Back Bay	39	39	56	68	47	60	70	83	96	88	107	91
Ruggles-Mass Ave	40	39	55	68	47	59	69	81	94	86	106	91
Roxbury Crossing-Ruggles	39	31	51	63	47	60	66	79	90	81	102	87
Jackson Sq-Roxbury Crossing	37	30	49	62	48	60	65	75	85	75	96	80
Stony Brook-Jackson Sq	33	27	41	55	41	55	58	66	76	69	89	72
Green St-Stony Brook	29	23	36	49	36	48	49	55	62	56	71	55
Forest Hills-Green St	24	18	30	41	30	41	40	44	47	43	54	39

**Figure 14 Passengers per Vehicle
Orange Line Southbound - PM
2040 No Build**

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Oak Grove-Malden Ctr	3	4	3	4	3	2	2	2	3	2	2	2
Malden Ctr-Wellington	11	16	12	14	9	10	12	11	11	12	10	10
Wellington-Assembly	16	22	19	21	13	16	17	16	17	18	16	14
Assembly-Sullivan Sq	13	19	16	18	11	13	14	14	14	16	14	12
Sullivan Sq-Community College	26	33	29	30	19	23	24	25	24	28	22	20
Community College-North Station	33	41	35	49	29	31	32	31	33	46	31	26
North Station-Haymarket	36	48	42	54	36	37	42	42	44	59	40	34
Haymarket-State	40	52	45	57	41	40	47	48	52	62	44	36
State-Downtown Crossing	46	54	49	58	46	44	55	57	71	71	54	45
Downtown Crossing-Chinatown	65	77	71	77	59	58	78	77	97	99	81	68
Chinatown-Tufts Medical Ctr	65	76	70	76	60	59	78	79	100	102	82	71
Tufts Medical Ctr-Back Bay	60	71	65	71	57	56	74	76	96	95	77	67
Back Bay-Mass Ave	61	68	60	66	55	53	72	72	95	90	74	63
Mass Ave-Ruggles	62	68	59	66	55	53	73	71	93	87	73	61
Ruggles-Roxbury Crossing	53	61	52	60	49	48	67	64	83	76	66	58
Roxbury Crossing-Jackson Sq	54	56	51	56	46	44	64	59	77	69	61	52
Jackson Sq-Stony Brook	47	49	45	49	41	39	58	54	69	63	56	47
Stony Brook-Green St	40	42	38	42	34	33	47	45	57	51	45	38
Green St-Forest Hills	34	34	32	34	28	26	38	34	42	38	34	28

**Figure 15 Passengers per Vehicle
Green Line Southbound - AM
2040 No Build**

Route Segment (Branches)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM															
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM				
Lechmere-Science Park (E)	6	5	9	7	5	9	12	11	18	18	16	18				
Science Park-North Station (E)	6	5	9	7	6	9	12	12	19	19	17	18				
North Station-Haymarket (C,E)	8	16	18	15	19	22	26	31	46	44	45	33				
Haymarket-Gov Ctr (C,E)	11	22	23	20	22	27	27	32	47	44	47	34				
Gov Ctr-Park St (B,C,D,E)	26	39	41	37	36	45	42	41	51	56	56	40				
Park St-Boylston (B,C,D,E)	28	41	50	54	51	67	68	67	78	87	83	71				
Boylston-Arlington (B,C,D,E)	28	41	50	54	51	67	67	66	78	85	81	69				
Arlington-Copley (B,C,D,E)	24	35	42	47	45	58	56	53	61	68	63	54				
Copley-Hynes (B,C,D)	19	25	36	44	46	57	52	50	59	76	54	35				
Hynes-Kenmore (B,C,D)	19	24	35	43	45	55	50	47	55	70	46	31				
Copley-Prudential (E)	25	36	44	58	55	70	70	63	82	84	77	67				
Prudential-Symphony (E)	21	32	38	51	49	58	56	50	62	65	56	53				

**Figure 16 Passengers per Vehicle
Green Line Northbound - PM
2040 No Build**

Route Segment (Branches)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Science Park-Lechmere (E)	18	17	17	15	13	18	14	15	24	17	18	17
North Station-Science Park (E)	19	18	19	16	14	20	16	16	25	18	20	18
Haymarket-North Station (C,E)	20	23	24	24	21	29	27	31	41	29	29	28
Gov Ctr-Haymarket (C,E)	24	27	29	27	24	32	31	34	44	33	33	32
Park St-Gov Ctr (B,C,D,E)	38	46	46	45	37	48	48	44	58	42	46	44
Bolyston-Park St (B,C,D,E)	61	72	67	69	61	75	77	75	101	74	82	85
Arlington-Bolyston (B,C,D,E)	64	75	70	71	62	76	79	75	101	76	86	90
Copley-Arlington (B,C,D,E)	60	70	68	70	56	69	70	65	84	66	80	84
Hynes-Copley (B,C,D)	45	53	54	59	48	55	58	57	67	52	73	61
Kenmore-Hynes (B,C,D)	45	51	54	58	48	52	56	55	62	50	72	59
Prudential-Copley (E)	107	115	107	111	74	110	105	92	125	106	107	161
Symphony-Prudential (E)	98	101	91	99	62	93	91	76	100	87	85	139

**Figure 17 Passengers per Vehicle
Green Line Northbound - AM
2040 No Build**

Route Segment (Branches)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM															
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM				
Science Park-Lechmere (E)	5	6	6	7	6	10	13	9	13	16	16	12				
North Station-Science Park (E)	6	7	7	8	7	11	16	12	16	19	20	13				
Haymarket-North Station (C,E)	5	8	6	6	8	10	16	12	15	18	19	13				
Gov Ctr-Haymarket (C,E)	6	8	6	7	8	10	17	13	16	21	22	17				
Park St-Gov Ctr (B,C,D,E)	7	13	10	13	14	17	28	22	35	41	39	31				
Bolyston-Park St (B,C,D,E)	8	14	11	17	22	28	48	36	61	74	71	53				
Arlington-Bolyston (B,C,D,E)	10	16	13	19	24	31	54	41	68	82	79	61				
Copley-Arlington (B,C,D,E)	10	17	14	20	26	34	59	46	74	89	87	68				
Hynes-Copley (B,C,D)	12	18	17	25	32	37	72	51	89	109	104	80				
Kenmore-Hynes (B,C,D)	12	19	17	25	33	39	74	52	93	115	108	84				
Prudential-Copley (E)	9	18	10	11	17	33	49	47	56	65	68	56				
Symphony-Prudential (E)	7	16	9	10	13	29	41	39	44	54	56	48				

**Figure 18 Passengers per Vehicle
Green Line Southbound - PM
2040 No Build**

Route Segment (Branches)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Lechmere-Science Park (E)	11	14	17	15	13	18	13	14	17	31	21	16
Science Park-North Station (E)	13	16	20	17	16	21	16	17	21	38	23	20
North Station-Haymarket (C,E)	16	16	19	16	19	17	15	16	23	41	21	19
Haymarket-Gov Ctr (C,E)	19	19	23	19	21	20	17	19	26	42	24	20
Gov Ctr-Park St (B,C,D,E)	31	32	38	33	34	33	31	32	56	69	41	32
Park St-Boylston (B,C,D,E)	43	48	57	53	45	49	46	52	88	119	74	55
Boylston-Arlington (B,C,D,E)	46	51	60	59	50	52	50	58	97	127	80	62
Arlington-Copley (B,C,D,E)	48	52	63	63	53	54	55	62	107	134	85	68
Copley-Hynes (B,C,D)	51	53	67	66	55	59	62	71	123	151	98	80
Hynes-Kenmore (B,C,D)	50	51	63	67	56	59	63	73	126	152	99	83
Copley-Prudential (E)	42	49	53	52	51	47	44	53	90	110	68	56
Prudential-Symphony (E)	33	39	44	44	44	36	35	42	76	87	55	45

Route Segment	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM		6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM		6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM		6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM		7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM		7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM		7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM		7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM		8:00AM · 8:15AM · 8:30AM · 8:45AM		8:15AM · 8:30AM · 8:45AM		8:30AM · 8:45AM		
	5	10	15	8	9	17	13	15	16	19	17	17	13	15	16	19	17	17	13	15	16	19	17
Wonderland-Revere Beach	5	10	15	8	9	17	13	15	16	19	17	17	13	15	16	19	17	17	13	15	16	19	17
Revere Beach-Beachmont	10	17	23	14	14	26	20	23	24	28	25	25	20	23	24	28	25	25	20	23	24	28	25
Beachmont-Suffolk Downs	14	23	34	20	21	35	27	33	33	39	34	37	27	33	33	39	34	37	27	33	33	39	34
Suffolk Downs-Orient Heights	14	22	33	19	21	34	26	32	32	38	33	36	26	32	32	38	33	36	26	32	32	38	33
Orient Heights-Wood Island	17	27	37	23	24	37	29	35	36	41	39	40	29	35	36	41	39	40	29	35	36	41	39
Wood Island-Airport	21	30	42	25	27	42	32	38	40	44	42	43	32	38	40	44	42	43	32	38	40	44	42
Airport-Maverick	32	48	63	40	41	61	47	54	57	63	61	62	47	54	57	63	61	62	47	54	57	63	61
Maverick-Aquarium	54	65	92	58	54	84	64	72	73	83	79	77	64	72	73	83	79	77	64	72	73	83	79
Aquarium-State	51	62	86	53	51	78	58	64	66	74	70	67	58	64	66	74	70	67	58	64	66	74	70
State-Govt Ctr	29	33	50	29	31	48	36	37	37	43	42	38	36	37	37	43	42	38	36	37	37	43	42
Gov Ctr-Bowdoin	2	3	7	4	4	5	5	6	6	6	5	4	5	6	6	6	5	4	5	6	6	6	5

Figure 20 Passengers per Vehicle
Blue Line Northbound - PM
2040 No Build

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Revere Beach-Wonderland	6	7	7	9	12	11	13	17	22	15	14	13
Beachmont-Revere Beach	10	13	13	14	19	17	19	24	30	21	20	18
Suffolk Downs-Beachmont	14	19	18	20	26	23	26	33	42	29	28	24
Orient Heights-Suffolk Downs	15	18	18	19	26	23	26	32	42	29	27	24
Wood Island-Orient Heights	17	21	21	23	30	26	29	36	49	32	31	27
Airport-Wood Island	19	24	24	25	33	29	32	38	53	34	34	29
Maverick-Airport	29	37	35	37	46	42	46	53	72	48	47	40
Aquarium-Maverick	42	54	48	52	62	58	61	68	89	63	60	52
State-Aquarium	39	52	46	50	57	53	57	61	80	57	54	48
Gov Ctr-State	26	32	30	32	33	34	35	37	45	33	34	29
Bowdoin- Gov Ctr	3	3	4	4	5	5	4	6	8	5	3	3

[illegible]

Figure 22 Passengers per Vehicle
Blue Line Southbound - PM
2040 No Build

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Wonderland-Revere Beach	2	3	3	2	3	3	2	3	3	2	1	3
Revere Beach-Beachmont	5	6	5	5	5	6	4	5	5	5	4	4
Beachmont-Suffolk Downs	6	7	7	6	6	8	5	6	7	6	5	5
Suffolk Downs-Orient Heights	6	8	7	6	7	8	5	6	8	6	6	6
Orient Heights-Wood Island	7	9	9	8	8	10	7	8	9	8	7	7
Wood Island-Airport	8	10	10	9	9	12	8	10	11	9	8	7
Airport-Maverick	13	16	15	15	13	17	13	16	18	15	13	11
Maverick-Aquarium	19	24	23	21	21	22	20	24	24	22	18	15
Aquarium-State	19	22	22	20	20	22	20	23	25	22	18	15
State-Govt Ctr	13	15	15	14	14	14	13	14	15	13	12	9
Gov Ctr-Bowdoin	0	1	1	1	0	0	0	0	1	0	0	0

Appendix H

Passengers per Vehicle in the 2040 Build Scenario

Appendix F shows the passengers per vehicle that were used for the 2040 Build Scenario in Figures 7 through 22.

The route segments and time periods with crowding are highlighted and indicate the crowding icon that is used in Figures 7 through 22.

Indicates "Overburdened" Icon



Indicates "Overcrowded" Icon



Indicates "Unacceptable" Icon



**Figure 7 Passengers per Vehicle
Red Line Southbound - AM
2040 Build**

Route Segment (Branch)	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Alewife-Davis	4	9	7	18	15	21	27	34	30	33	40	36
Davis-Porter	9	15	15	34	29	41	50	68	64	69	88	82
Porter-Harvard	12	19	18	48	35	50	69	92	86	90	126	103
Harvard-Central	17	26	25	56	44	64	85	106	100	112	149	122
Central-Kendall	20	36	30	64	53	75	94	120	118	137	173	148
Kendall-Charles/MGH	20	36	29	59	52	73	89	109	110	127	153	132
Charles/MGH-Park St	18	31	24	48	48	67	83	100	104	120	144	125
Park St-Downtown Crossing	18	32	22	46	51	60	68	77	83	91	108	86
Downtown Crossing-South Station	21	43	26	52	63	67	67	69	74	80	89	71
South Station-Broadway	17	36	23	44	56	54	43	37	36	36	38	36
Broadway-Andrew	17	34	21	44	55	53	41	35	33	34	36	34
Andrew-JFK/UMASS	14	27	18	39	48	46	37	30	29	30	32	29
JFK/UMASS-N Quincy (Braintree)	11	20	14	21	42	30	25	28	28	22	19	19
N Quincy-Wollaston (Braintree)	9	18	11	17	35	20	17	19	19	14	14	15
Wollaston-Quincy Ctr (Braintree)	9	17	11	18	35	18	15	17	18	13	12	15
Quincy Ctr-Quincy Adams (Braintree)	6	12	6	8	13	8	7	9	7	6	5	5
Quincy Adams-Braintree (Braintree)	4	6	4	4	8	4	2	3	3	2	2	2
JFK/UMASS-Savin Hill (Ashmont)	9	13	13	24	17	13	11	13	10	10	10	9
Savin Hill-Fields Corner (Ashmont)	9	12	13	17	13	12	10	13	10	9	9	9
Fields Corner-Shawmut (Ashmont)	9	9	12	17	11	9	7	9	8	6	6	7
Shawmut-Ashmont (Ashmont)	8	8	11	16	10	8	6	7	5	5	4	6

**Figure 8 Passengers per Vehicle
Red Line Northbound - PM
2040 Build**

Route Segment (Branch)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Davis-Alewife	14	11	12	19	18	21	29	24	34	38	29	24
Porter-Davis	26	21	23	35	32	36	51	47	70	79	65	53
Harvard-Porter	34	28	30	44	42	55	65	63	95	105	86	71
Central-Harvard	49	41	43	62	55	72	89	81	123	141	114	91
Kendall-Central	58	48	50	74	63	79	101	88	141	167	140	108
Charles/MGH-Kendall	59	48	49	71	59	69	95	76	127	155	130	100
Park St-Charles/MGH	63	49	48	71	57	66	89	72	119	149	125	96
Downtown Crossing-Park St	55	45	44	64	44	56	70	59	88	121	104	73
South Station-Downtown Crossing	59	50	50	71	43	55	71	59	76	110	99	66
Broadway-South Station	54	46	46	64	32	42	48	40	39	59	56	35
Andrew-Broadway	53	46	45	61	31	40	46	38	37	54	53	34
JFK/UMASS-Andrew	46	40	37	52	27	34	41	33	32	46	46	30
N Quincy-JFK/UMASS (Braintree)	38	26	27	40	23	29	39	31	26	55	38	30
Wollaston-N Quincy (Braintree)	32	23	23	33	18	23	31	24	22	33	26	24
Quincy Ctr-Wollaston (Braintree)	31	20	20	29	16	20	28	22	19	29	23	22
Quincy Adams-Quincy Ctr (Braintree)	12	7	11	16	9	10	15	13	11	14	12	14
Braintree-Quincy Adams (Braintree)	8	4	6	9	5	7	9	6	5	6	7	4
Savin Hill-JFK/UMASS (Ashmont)	33	32	25	32	17	22	24	18	22	20	23	13
Fields Corner-Savin Hill (Ashmont)	31	28	20	28	15	18	21	16	20	17	19	11
Shawmut-Fields Corner (Ashmont)	26	27	13	19	11	13	15	11	13	11	12	8
Ashmont-Shawmut (Ashmont)	24	25	10	15	9	10	13	9	11	9	9	7

**Figure 9 Passengers per Vehicle
Red Line Northbound - AM
2040 Build**

Route Segment (Branch)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM																
	6:00AM	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM				
Davis-Alewife	6	7	6	7	8	8	8	8	10	10	8	6	6				
Porter-Davis	7	8	8	9	12	11	11	11	14	14	13	10	10				
Harvard-Porter	7	10	10	12	16	14	13	13	18	16	17	13	13				
Central-Harvard	14	22	19	22	30	28	29	29	38	37	42	40	30				
Kendall-Central	16	27	23	30	39	36	38	38	49	48	51	52	36				
Charles/MGH-Kendall	20	37	33	41	51	49	54	54	74	73	80	78	59				
Park St-Charles/MGH	32	60	55	60	68	64	73	73	94	89	93	90	70				
Downtown Crossing-Park St	33	62	63	77	88	80	91	91	122	118	119	114	99				
South Station-Downtown Crossing	35	68	70	88	96	89	100	100	141	139	134	130	121				
Broadway-South Station	44	68	76	92	104	98	114	114	156	158	150	153	151				
Andrew-Broadway	45	69	77	95	107	100	116	116	159	158	147	150	150				
JFK/UMASS-Andrew	40	61	69	89	97	92	106	106	144	143	132	136	134				
N Quincy-JFK/UMASS (Braintree)	50	125	75	138	136	122	183	183	156	179	186	187	166				
Wollaston-N Quincy (Braintree)	41	102	62	112	111	98	151	151	129	142	148	147	125				
Quincy Ctr-Wollaston (Braintree)	32	86	50	91	93	80	125	125	104	117	116	120	104				
Quincy Adams-Quincy Ctr (Braintree)	22	53	34	60	57	50	79	79	65	74	63	64	59				
Braintree-Quincy Adams (Braintree)	14	35	24	37	37	33	51	51	44	43	31	22	25				
Savin Hill-JFK/UMASS (Ashmont)	56	54	61	97	81	112	84	84	119	84	83	107	100				
Fields Corner-Savin Hill (Ashmont)	53	46	55	87	76	106	78	78	105	70	69	92	86				
Shawmut-Fields Corner (Ashmont)	37	33	37	63	55	80	60	60	78	58	55	75	69				
Ashmont-Shawmut (Ashmont)	31	22	29	50	43	64	46	46	62	43	42	58	52				

**Figure 10 Passengers per Vehicle
Red Line Southbound - PM
2040 Build**

Route Segment (Branch)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Alewife-Davis	7	8	7	6	6	7	9	7	9	9	10	10
Davis-Porter	16	17	14	13	14	13	16	13	15	16	16	16
Porter-Harvard	20	22	18	16	18	17	19	16	20	22	20	20
Harvard-Central	40	50	42	36	39	41	39	30	43	49	39	38
Central-Kendall	50	59	53	44	51	51	49	38	58	61	48	47
Kendall-Charles/MGH	59	69	65	51	71	65	67	53	86	87	65	63
Charles/MGH-Park St	73	81	89	63	92	78	90	65	108	100	77	73
Park St-Downtown Crossing	87	94	97	76	119	90	110	81	142	115	87	84
Downtown Crossing-South Station	94	102	101	81	127	97	121	92	159	125	95	90
South Station-Broadway	100	107	104	86	136	106	129	105	193	136	112	103
Broadway-Andrew	103	109	106	87	141	109	131	108	196	138	112	104
Andrew-JFK/UMASS	93	98	97	80	131	100	121	99	177	126	101	94
JFK/UMASS-N Quincy (Braintree)	101	108	87	97	172	146	129	120	170	155	117	104
N Quincy-Wollaston (Braintree)	86	89	74	81	141	120	103	97	138	125	93	82
Wollaston-Quincy Ctr (Braintree)	74	76	64	67	116	103	84	79	115	102	76	69
Quincy Ctr-Quincy Adams (Braintree)	42	43	40	40	71	61	50	46	67	55	43	37
Quincy Adams-Braintree (Braintree)	25	25	23	25	43	35	30	25	34	28	20	17
JFK/UMASS-Savin Hill (Ashmont)	79	75	94	59	84	57	91	64	156	78	68	66
Savin Hill-Fields Corner (Ashmont)	78	70	85	54	75	51	81	58	136	69	60	55
Fields Corner-Shawmut (Ashmont)	58	49	67	40	54	40	61	46	103	53	47	43
Shawmut-Ashmont (Ashmont)	47	40	52	32	41	30	45	35	79	41	36	33

**Figure 11 Passengers per Vehicle
Orange Line Southbound - AM
2040 Build**

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Oak Grove-Malden Ctr	16	16	22	18	25	31	37	28	32	42	47	33
Malden Ctr-Wellington	35	41	41	45	52	69	78	59	79	102	120	92
Wellington-Assembly	44	50	55	60	65	83	97	73	100	127	152	118
Assembly-Sullivan Sq	55	62	69	75	80	103	120	91	124	158	189	147
Sullivan Sq-Community College	71	75	76	83	84	105	124	101	134	166	199	154
Community College-North Station	78	83	82	89	90	117	136	110	143	177	218	169
North Station-Haymarket	68	83	86	84	95	122	144	125	174	183	247	176
Haymarket-State	67	86	85	83	91	115	133	115	161	168	228	159
State-Downtown Crossing	68	87	87	82	84	107	115	96	132	135	184	126
Downtown Crossing-Chinatown	67	80	87	81	78	105	109	93	124	127	174	125
Chinatown-Tufts Medical Ctr	61	76	82	75	74	99	101	86	114	115	156	111
Tufts Medical Ctr-Back Bay	52	64	67	62	60	82	83	70	91	94	130	92
Back Bay-Mass Ave	40	51	56	49	44	55	55	38	50	51	64	49
Mass Ave-Ruggles	39	50	54	48	42	52	50	35	44	46	56	42
Ruggles-Roxbury Crossing	20	27	29	26	21	23	18	15	17	19	23	16
Roxbury Crossing-Jackson Sq	19	24	26	23	17	18	17	14	15	16	19	14
Jackson Sq-Stony Brook	22	24	26	22	14	15	14	12	13	14	15	11
Stony Brook-Green St	23	24	26	21	14	14	14	11	11	12	12	9
Green St-Forest Hills	23	22	25	19	12	10	10	8	8	10	9	8

Figure 12 Passengers per Vehicle
Orange Line Northbound - PM
2040 Build

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Malden Ctr-Oak Grove	11	12	14	18	24	20	25	28	38	35	28	25
Wellington-Malden Ctr	34	32	35	45	52	46	56	61	91	82	72	63
Assembly-Wellington	45	42	46	59	67	58	73	75	115	102	92	80
Sullivan Sq-Assembly	65	61	67	86	97	84	106	109	168	149	135	117
Community College-Sullivan Sq	65	60	65	81	91	77	96	99	149	136	124	106
North Station-Community College	77	73	74	88	99	86	108	109	163	156	145	120
Haymarket-North Station	75	72	76	94	107	92	112	124	183	166	147	125
State-Haymarket	71	69	73	91	99	86	104	115	168	155	138	119
Downtown Crossing-State	70	72	73	88	92	77	92	98	139	135	118	104
Chinatown-Downtown Crossing	76	81	73	89	94	77	93	95	133	136	114	104
Tufts Medical Ctr-Chinatown	70	76	70	84	85	71	88	89	122	129	109	98
Back Bay-Tufts Medical Ctr	62	68	59	71	70	60	73	75	101	110	94	83
Mass Ave-Back Bay	52	63	53	65	56	46	53	56	61	68	61	55
Ruggles-Mass Ave	50	61	53	63	52	43	50	52	58	63	56	50
Roxbury Crossing-Ruggles	27	38	33	35	30	25	25	25	31	30	30	25
Jackson Sq-Roxbury Crossing	26	28	30	31	27	21	22	23	28	28	27	24
Stony Brook-Jackson Sq	23	26	28	27	24	17	19	19	23	21	22	20
Green St-Stony Brook	20	23	26	23	21	16	16	16	20	17	18	18
Forest Hills-Green St	17	21	19	16	18	13	13	13	17	14	15	14

Figure 13 Passengers per Vehicle
Orange Line Northbound - AM
2040 Build

Route Segment	6:00AM - 6:15AM	6:15AM - 6:30AM	6:30AM - 6:45AM	6:45AM - 7:00AM	7:00AM - 7:15AM	7:15AM - 7:30AM	7:30AM - 7:45AM	7:45AM - 8:00AM	8:00AM - 8:15AM	8:15AM - 8:30AM	8:30AM - 8:45AM	8:45AM - 9:00AM
Malden Ctr-Oak Grove	3	3	2	3	2	1	2	2	2	1	1	2
Wellington-Malden Ctr	7	8	7	10	7	7	7	9	12	8	8	6
Assembly-Wellington	12	13	12	15	11	12	12	16	20	13	13	10
Sullivan Sq-Assembly	37	40	38	47	33	36	37	49	62	40	39	31
Community College-Sullivan Sq	39	45	46	54	40	40	43	47	57	41	40	31
North Station-Community College	38	52	65	68	42	41	51	65	85	54	48	39
Haymarket-North Station	46	58	77	80	52	52	67	80	96	75	69	63
State-Haymarket	43	54	74	78	52	52	70	82	97	80	77	73
Downtown Crossing-State	40	49	74	78	55	55	76	92	114	102	106	102
Chinatown-Downtown Crossing	47	51	80	92	67	74	93	108	130	128	140	132
Tufts Medical Ctr-Chinatown	46	51	80	90	66	73	93	109	131	130	145	135
Back Bay-Tufts Medical Ctr	44	49	75	83	60	69	90	105	129	127	137	129
Mass Ave-Back Bay	47	47	68	82	57	72	85	100	115	106	129	110
Ruggles-Mass Ave	47	46	66	81	56	70	82	96	112	102	125	108
Roxbury Crossing-Ruggles	45	37	60	74	55	70	77	92	105	95	119	102
Jackson Sq-Roxbury Crossing	43	35	58	73	56	70	76	88	99	88	112	94
Stony Brook-Jackson Sq	38	31	48	64	48	64	67	77	88	80	103	84
Green St-Stony Brook	33	26	41	56	41	55	56	63	71	65	82	63
Forest Hills-Green St	28	21	35	47	35	47	47	51	55	49	63	45

**Figure 14 Passengers per Vehicle
Orange Line Southbound - PM
2040 Build**

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Oak Grove-Malden Ctr	4	5	3	6	4	2	3	3	4	3	3	3
Malden Ctr-Wellington	13	19	15	17	10	12	14	12	13	14	12	12
Wellington-Assembly	18	26	22	25	15	19	20	19	20	22	19	17
Assembly-Sullivan Sq	37	53	44	51	30	37	40	39	40	44	39	34
Sullivan Sq-Community College	53	67	59	62	38	48	50	51	49	57	46	41
Community College-North Station	58	73	61	85	51	54	55	54	58	81	54	46
North Station-Haymarket	60	80	70	90	60	61	70	71	74	98	67	57
Haymarket-State	62	81	70	88	64	61	72	74	80	96	68	56
State-Downtown Crossing	68	80	74	86	68	65	83	85	105	106	80	67
Downtown Crossing-Chinatown	85	102	93	101	78	77	103	101	128	131	107	90
Chinatown-Tufts Medical Ctr	83	98	90	98	76	75	101	102	128	130	105	91
Tufts Medical Ctr-Back Bay	77	90	83	90	73	71	94	96	122	122	98	85
Back Bay-Mass Ave	74	82	72	80	67	64	87	87	114	108	90	76
Mass Ave-Ruggles	73	81	70	79	66	64	86	85	110	104	87	72
Ruggles-Roxbury Crossing	63	73	61	71	58	57	79	75	99	90	78	68
Roxbury Crossing-Jackson Sq	64	66	60	67	55	52	76	70	91	82	72	62
Jackson Sq-Stony Brook	56	58	53	58	48	46	68	63	82	74	66	56
Stony Brook-Green St	47	49	45	49	40	38	55	52	66	60	52	44
Green St-Forest Hills	40	41	37	40	33	31	45	40	50	45	40	33

**Figure 15 Passengers per Vehicle
Green Line Southbound - AM
2040 Build**

Route Segment (Branches)	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM														
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM			
Lechmere-Science Park (E)	24	19	37	31	23	37	49	48	74	76	69	75			
Science Park-North Station (E)	23	20	35	30	23	37	50	49	75	77	68	74			
North Station-Haymarket (C,E)	16	31	35	29	37	44	50	61	90	85	88	65			
Haymarket-Gov Ctr (C,E)	19	39	40	36	39	48	49	57	84	78	84	60			
Gov Ctr-Park St (B,C,D,E)	34	51	53	49	48	59	56	54	67	73	74	52			
Park St-Boylston (B,C,D,E)	35	51	63	68	64	83	84	84	98	109	104	88			
Boylston-Arlington (B,C,D,E)	35	52	64	68	66	85	86	84	99	109	103	87			
Arlington-Copley (B,C,D,E)	33	47	56	64	61	78	76	72	83	92	85	73			
Copley-Hynes (B,C,D)	31	40	58	71	74	91	83	80	95	121	86	56			
Hynes-Kenmore (B,C,D)	29	36	53	65	68	82	75	71	83	106	69	47			
Copley-Prudential (E)	29	42	51	67	64	81	81	74	96	98	89	79			
Prudential-Symphony (E)	34	51	62	82	80	94	92	82	100	106	91	87			

**Figure 16 Passengers per Vehicle
Green Line Northbound - PM
2040 Build**

Route Segment (Branches)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Science Park-Lechmere (E)	58	54	55	48	43	59	46	48	75	54	58	54
North Station-Science Park (E)	58	55	56	49	42	60	47	50	76	56	59	54
Haymarket-North Station (C,E)	40	46	47	48	42	57	53	61	82	58	57	56
Gov Ctr-Haymarket (C,E)	42	48	51	49	43	57	55	60	79	58	58	57
Park St-Gov Ctr (B,C,D,E)	49	60	60	58	48	62	63	57	76	55	60	57
Bolyston-Park St (B,C,D,E)	74	87	81	84	74	91	94	91	122	90	99	103
Arlington-Bolyston (B,C,D,E)	79	92	86	87	76	94	97	92	124	93	106	110
Copley-Arlington (B,C,D,E)	76	88	85	89	71	87	88	82	106	84	101	106
Hynes-Copley (B,C,D)	67	79	80	87	72	82	85	84	100	77	108	91
Kenmore-Hynes (B,C,D)	62	72	74	80	66	72	78	76	86	69	100	82
Prudential-Copley (E)	118	126	117	122	81	121	115	100	137	117	117	176
Symphony-Prudential (E)	131	135	122	133	82	125	122	102	134	116	113	186

**Figure 17 Passengers per Vehicle
Green Line Northbound - AM
2040 Build**

	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM
Route Segment (Branches)	6:15AM 6:30AM 6:45AM 7:00AM 7:15AM 7:30AM 7:45AM 8:00AM 8:15AM 8:30AM 8:45AM 9:00AM
Science Park-Lechmere (E)	42 52 50 59 52 88 117 82 112 137 140 100
North Station-Science Park (E)	47 51 53 57 51 85 123 88 117 146 150 100
Haymarket-North Station (C,E)	33 47 37 38 46 59 94 69 88 110 112 80
Gov Ctr-Haymarket (C,E)	26 38 30 34 39 50 83 60 76 97 104 80
Park St-Gov Ctr (B,C,D,E)	15 25 20 27 29 35 57 44 69 82 78 62
Bolyston-Park St (B,C,D,E)	13 23 18 26 35 44 75 57 96 115 112 83
Arlington-Bolyston (B,C,D,E)	15 24 19 28 36 46 80 62 102 122 119 91
Copley-Arlington (B,C,D,E)	15 24 20 29 37 48 84 65 105 126 124 97
Hynes-Copley (B,C,D)	15 24 22 33 41 49 93 66 116 142 135 104
Kenmore-Hynes (B,C,D)	15 24 22 32 42 50 94 67 119 147 138 108
Prudential-Copley (E)	16 33 18 21 33 62 91 88 105 122 127 106
Symphony-Prudential (E)	15 34 19 21 28 60 85 81 91 112 116 98

**Figure 18 Passengers per Vehicle
Green Line Southbound - PM
2040 Build**

Route Segment (Branches)	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Lechmere-Science Park (E)	72	86	105	93	84	113	84	91	110	197	130	98
Science Park-North Station (E)	74	88	109	95	87	116	88	94	115	209	128	109
North Station-Haymarket (C,E)	67	70	80	70	81	75	63	71	99	175	92	82
Haymarket-Gov Ctr (C,E)	66	66	80	66	73	68	60	65	90	147	82	71
Gov Ctr-Park St (B,C,D,E)	52	55	64	56	57	56	53	55	95	117	69	54
Park St-Boylston (B,C,D,E)	60	68	80	75	64	68	65	73	123	167	104	78
Boylston-Arlington (B,C,D,E)	63	70	82	80	69	71	68	79	132	174	109	85
Arlington-Copley (B,C,D,E)	63	69	84	84	70	71	73	82	141	177	112	90
Copley-Hynes (B,C,D)	63	66	83	83	68	74	78	88	154	189	122	100
Hynes-Kenmore (B,C,D)	62	63	78	83	70	73	78	90	156	187	122	103
Copley-Prudential (E)	67	78	85	84	82	76	71	85	144	176	109	91
Prudential-Symphony (E)	58	68	77	78	77	64	62	75	134	154	97	80

Figure 19 Passengers per Vehicle
Blue Line Southbound - AM
2040 Build

Route Segment	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM · 9:00AM															
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM				
Wonderland-Revere Beach	5	10	15	8	9	17	13	15	16	19	17	17				
Revere Beach-Beachmont	10	17	23	14	14	26	20	23	24	28	25	25				
Beachmont-Suffolk Downs	14	23	34	20	21	35	27	33	33	39	34	37				
Suffolk Downs-Orient Heights	14	22	33	19	21	34	26	32	32	38	33	36				
Orient Heights-Wood Island	17	27	37	23	24	37	29	35	36	41	39	40				
Wood Island-Airport	21	30	42	25	27	42	32	38	40	44	42	43				
Airport-Maverick	32	48	63	40	41	61	47	54	57	63	61	62				
Maverick-Aquarium	54	65	92	58	54	84	64	72	73	83	79	77				
Aquarium-State	51	62	86	53	51	78	58	64	66	74	70	67				
State-Govt Ctr	29	33	50	29	31	48	36	37	37	43	42	38				
Gov Ctr-Bowdoin	2	3	7	4	4	5	5	6	6	6	5	4				

Figure 20 Passengers per Vehicle
Blue Line Northbound - PM
2040 Build

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Revere Beach-Wonderland	9	12	12	14	20	17	21	27	35	25	23	21
Beachmont-Revere Beach	16	21	20	23	30	27	30	38	47	34	32	29
Suffolk Downs-Beachmont	20	25	24	27	36	32	36	45	58	40	39	33
Orient Heights-Suffolk Downs	18	23	22	24	32	29	32	40	53	36	34	29
Wood Island-Orient Heights	20	25	25	26	34	30	34	41	57	37	36	31
Airport-Wood Island	21	27	27	28	37	32	36	43	59	38	38	32
Maverick-Airport	31	39	37	39	49	45	49	56	76	51	49	42
Aquarium-Maverick	43	56	50	54	65	60	63	70	92	65	63	54
State-Aquarium	40	54	48	52	59	55	59	63	82	59	56	50
Gov Ctr-State	27	33	31	33	34	35	36	38	47	34	35	30
Bowdoin- Gov Ctr	3	3	4	4	5	5	4	6	8	5	3	3

Route Segment	6:00AM · 6:15AM · 6:30AM · 6:45AM · 7:00AM · 7:15AM · 7:30AM · 7:45AM · 8:00AM · 8:15AM · 8:30AM · 8:45AM															
	6:15AM	6:30AM	6:45AM	7:00AM	7:15AM	7:30AM	7:45AM	8:00AM	8:15AM	8:30AM	8:45AM	9:00AM	9:15AM	9:30AM	9:45AM	10:00AM
Revere Beach-Wonderland	2	3	3	2	3	3	2	2	2	2	1	2				
Beachmont-Revere Beach	4	6	5	3	4	4	3	3	3	3	3	3				
Suffolk Downs-Beachmont	6	7	7	3	5	5	4	3	4	5	4	4				
Orient Heights-Suffolk Downs	6	7	7	4	5	5	4	3	4	5	4	4				
Wood Island-Orient Heights	7	8	9	5	6	8	5	4	6	7	5	6				
Airport-Wood Island	9	12	12	8	7	9	6	5	6	8	6	6				
Maverick-Airport	11	18	23	15	14	15	9	7	10	11	7	8				
Aquarium-Maverick	15	22	33	22	19	23	14	12	15	18	12	14				
State-Aquarium	16	21	34	22	21	24	17	16	18	22	17	18				
Gov Ctr-State	11	12	16	12	11	15	11	10	16	17	13	15				
Bowdoin- Gov Ctr	0	0	0	0	0	0	0	0	0	0	0	1				

Figure 22 Passengers per Vehicle
Blue Line Southbound - PM
2040 Build

Route Segment	3:00PM - 3:15PM	3:15PM - 3:30PM	3:30PM - 3:45PM	3:45PM - 4:00PM	4:00PM - 4:15PM	4:15PM - 4:30PM	4:30PM - 4:45PM	4:45PM - 5:00PM	5:00PM - 5:15PM	5:15PM - 5:30PM	5:30PM - 5:45PM	5:45PM - 6:00PM
Wonderland-Revere Beach	2	3	3	2	3	3	2	3	3	2	1	3
Revere Beach-Beachmont	5	6	5	5	5	6	4	5	5	5	4	4
Beachmont-Suffolk Downs	6	7	7	6	6	8	5	6	7	6	5	5
Suffolk Downs-Orient Heights	6	8	7	6	7	8	5	6	8	6	6	6
Orient Heights-Wood Island	7	9	9	8	8	10	7	8	9	8	7	7
Wood Island-Airport	8	10	10	9	9	12	8	10	11	9	8	7
Airport-Maverick	13	16	15	15	13	17	13	16	18	15	13	11
Maverick-Aquarium	19	24	23	21	21	22	20	24	24	22	18	15
Aquarium-State	19	22	22	20	20	22	20	23	25	22	18	15
State-Govt Ctr	13	15	15	14	14	14	13	14	15	13	12	9
Gov Ctr-Bowdoin	0	1	1	1	0	0	0	0	1	0	0	0

Appendix I

Transportation Mitigation Practices in Study Area Municipalities

Arlington

The town of Arlington has no formal mechanism that requires developers to implement transportation mitigation measures connected to their project's traffic or transit impacts (beyond providing at least two and no more than 20 bicycle parking spaces, with one for every fifteen parking spaces above eight spaces¹), nor a threshold that requires a study of the impacts. Despite not having a site plan review ordinance to describe a standard process, developers' proposals must be approved by the town's Board of Selectmen, which receives support and recommendations from other departments and committees in the town government, before construction is permitted. The most important of these support entities is the Transportation Advisory Committee (TAC).

The TAC, made up of local and knowledgeable transportation professionals, has been the force behind the town's mitigation efforts. The TAC was voted into existence in 2001 to assist the Board of Selectmen in dealing with parking, traffic, and transportation issues in the town. The TAC works with the Department of Planning and Community Development, the Department of Public Works, and the Director of Police Services for town transportation studies, as well as with the Board of Selectmen when requested to study developer's traffic studies or citizen complaints. In effect, the committee functions as on-call consultants for the Board of Selectmen. According to a memo produced in 2004, TAC's decision criteria for evaluating transportation impacts of development projects includes:

- Safety
- Mobility
- Equity
- Environmental and Public Health
- Priority

The TAC screens the need for traffic calming by investigating traffic volume, vehicle classification, speed, cut-through traffic, crashes, existing geometry, and nearby trip generators. It then reviews the applicability, suitability, feasibility, user considerations, and impact of the requested measure.

¹ Arlington, Massachusetts, Zoning Bylaws § 8.8.3

Based on TAC reviews and recommendations, several transportation mitigation measures have been implemented and paid for by developers as conditions of obtaining a building permit. Where the Minuteman Bikeway crosses Mill Street, developers installed a warning system that flashes lights and sounds when a person walking or biking is about to approach the popular crossing. An Opticom device for the intersection of Massachusetts Avenue and Route 60 was purchased to allow for emergency vehicles to control nearby traffic signals and preempt changes to increase response times. Intersection geometry adjustments and signal retiming were done at the intersection of Massachusetts Avenue and Route 16 to allow for different turning coordination.

Boston

The Boston Redevelopment Authority (BRA) adopted Article 80 of the zoning code in 1996 to provide guidelines for review processes for development projects of different scales:

- Large projects (Article 80B): adding more than 50,000 square feet
- Planned Development Areas (Article 80C): new overlay zoning districts for projects greater than one acre
- Institutional Master Plans (Article 80D): projects relating to academic or medical campuses
- Small projects (Article 80E): adding more than 20,000 square feet

The Article 80 process often includes a review of transportation impacts, and it is a required component for approval of large projects. After a Letter of Intent is filed with the BRA, the Project Notification Form (PNF) includes transportation analysis and should identify mitigation efforts expected to be included in the final constructed project. A Draft Project Impact Report provides preliminary traffic impact modeling results further refined into the Final Project Impact Report, after determining adequacy in conjunction with the Boston Transportation Department (BTD) review process. This transportation review, undertaken in coordination with the BTD, focuses on traffic generation, parking, and curb-cut impacts, as well as requirements of the Boston Air Pollution Control Commission.

Prior to the issuance of a building permit, all projects must sign a Construction Management Plan (CMP) with the BTD that specifies what measures will be in place to manage transportation impacts during construction, and large projects must sign a Transportation Access Plan Agreement (TAPA). The extent and detail of the analyses and modeling required depends on the size, location, and complexity of the projects under review, and the TAPA may include findings and discussion related to all of the following components:

- Parking
- Loading
- Access
- Vehicular traffic
- Public transportation
- Pedestrian circulation
- Access plan
- Continued monitoring

The BTD employs a district-based approach to reviewing the parking component of proposed development projects, wherein proposals are evaluated based on the character of the neighborhood, the existing capacity of the roadways and transit infrastructure, the cumulative impact on all proposed projects in the vicinity, constraints by other parking regulations in the area, and programs offered by local Transportation Management Associations (TMAs). New TAPA guidelines put in place through Access Boston 2000-2010 require developers to include bicycle facilities and programs to encourage car sharing.

As a result of the new guidelines established by Access Boston 2000-2010, bicycle parking and car-sharing programs, as well as orientation packets with transit information for residents and employees, on-site transportation coordinators, and project websites containing transit information are the most frequent mitigation measures identified in PNFs submitted to the BRA. Electric vehicle charging stations, transit pass subsidies, and participation in TMAs are also popular measures.

Brookline

Brookline starts considering mitigation at the beginning of the town's plan review process. A traffic impact study is required of Major Impact Projects (identified as 16-plus units of housing or at least 25,000 square feet of nonresidential space) or asked for specifically by the Planning Board for projects that do not fit into clear land-use categories and therefore have uncertain impacts. Based on the results of the study, the Planning and Community Development Department and the Transportation Division of the Department of Public Works negotiate case-by-case mitigation with developers.

Frequent TDM measures required of developers include sidewalk improvements, bicycle parking and showers, and geometric layout changes. Several recent projects, including 2 Brookline Place, agreed to a capped target percentage for single-occupancy vehicle mode share for employees, which must be annually monitored and achieved, or additional mitigation measures would be required. Additionally, the developer of 10 Brookline Place and the town of Brookline

agreed to spend one percent of hard construction costs on transportation mitigation measures at the Brookline Village Green Line station.

In the future, Brookline planners hope to adopt a town-wide policy applicable to all projects similar to the City of Cambridge's Parking and Transportation Demand Management ordinance to provide clear expectations for developers. With more standardized guidelines, obtaining permits would entail less uncertainty and timeline risk and regulations would be more development-friendly.

This new ordinance is being advanced for a number of other reasons. There is ongoing growth pressure in the Longwood Medical Area, near Boston University and Boston College, in the Fenway, and along Route 9 in Newton that is projected to bring additional traffic through the town of Brookline. Additionally, many of the housing units developed in the past 15 years did not meet the Major Impact Project threshold and did not have their traffic impacts studied. Finally, there continues to be a moderate pace of commercial development near transit stations.

Although the ordinance is still under development, it is likely to include the following two components: 1) TDM points above a certain threshold, based on project square footage, will be required before a project is approved, and 2) projects further from a transit station will get more credits for implementing measures than those closer to a transit station.

Cambridge

The city of Cambridge has a history of transportation mitigation policies dating to 1992. Three regulatory avenues exist through which development proposals must identify the transportation mitigation measures to be included: the Parking and Transportation Demand Management Ordinance (PTDM); a city-wide Vehicle Trip Reduction Ordinance; and the Cambridge Redevelopment Authority's (CRA's) Land Development Agreements.

The PTDM ordinance, adopted in 1998 and made permanent in 2006, is managed by the City's Community Development Department (CDD) and its Traffic, Parking, and Transportation Department (TPTD). When an owner of nonresidential property proposes to add parking spaces above the number already registered with the city, a PTDM plan must be approved before a city permit is granted. Small project PTDM plans, applicable if total parking equals 5 to 19 spaces, require the implementation of three of nine TDM measures. Large project PTDM plans apply if total parking is 20 or more spaces. Large projects require a single-occupancy vehicle mode-share commitment, a comprehensive

set of TDM measures, and annual monitoring and reporting that includes an employee/patron survey of trip origin and mode.

Article 19 on Project Review of the Cambridge zoning regulations requires a traffic impact study that looks at existing transportation conditions, intersection crash history, projected trips in the build condition with added growth rate, and other area projects' trips in order to anticipate future transportation conditions. The PTDM plan process begins when a developer submits a draft to the CDD. A PTDM officer issues a draft decision with recommendations for revisions. The developer can then submit a final plan that is then approved, approved with additional conditions, or denied. PTDM officers look at five criteria of exceedances, identified in Article 19.25.11, that point out which impacts need to be mitigated:

- Project trip generation for a 24-hour period and at AM and PM peaks
- Changes in level of service at identified signalized intersections
- Increased traffic volume on residential streets
- Increased vehicle queues at identified signalized intersections
- Lack of sufficient pedestrian and bicycle facilities

Although PTDM officers negotiate PTDM plans with developers on a case-by-case basis, they employ a somewhat standard set of measures in order to increase consistency and make the development process more predictable. This can be seen in the Small Project Form's nine options. Sample TDM measures used in PTDM plans include:

- Transit subsidy for employees/tenants
- Free shuttle bus
- Bus shelter
- Market-rate parking fee charged directly to employees or patrons
- Electric vehicle charging stations
- Daily parking charge available for occasional drivers instead of only a monthly parking pass
- Bicycle parking above minimum zoning requirement
- Shower/locker room for bicyclists
- Financial incentive for walking or biking
- Emergency ride home program
- Car/vanpool matching aid
- Priority/discounted high-occupancy vehicle parking
- Hubway membership and station construction

- Transportation information—website and orientation packet and real-time screens
- Hiring of Cambridge residents
- On-site TDM coordinator
- TMA membership
- EZRide Shuttles
- Flexible work hours

Other measures of transportation mitigation that have been used in developer's PTDM plans include:

- Signal equipment and fiber optic cables
- Studying new turning lanes

The second mitigation avenue dates from 1992 when the City of Cambridge adopted a Vehicle Trip Reduction Ordinance (Chapter 10.17 of the Code of Ordinances) in response to the Clean Air Act amendments in 1990 and the Intermodal Surface Transportation Efficiency Act of 1991. The same year, the city's Bicycle Program was created and is administered within the Division of Environmental and Transportation Planning of the CDD. Recognizing that, "Increasing the use of commuting alternatives and reducing the number of trips by single-occupancy vehicles is beneficial for the City and the Commonwealth in reducing vehicle miles travelled, traffic and associated air pollution, fuel use, noise, and congestion . . ." ²

Cambridge created a city-wide program to encourage alternatives to vehicle trips and incentivize city departments, employers, institutions, owners of multiple-tenant buildings and complexes, and other organizations to use mass transit, bicycles, or walking. The effort included an expanded commuter mobility program, a bicycle and pedestrian mobility program, restrictions on visitor vehicle passes, fees for residential parking stickers, study of zoning revisions, improved coordination with the MBTA, regulations concerning idling vehicles, and taxicab improvements.

The last avenue by which transportation mitigation measures from developments are identified comes through the CRA, which operates separately from the CDD and works in the Kendall Square Urban Renewal Area (KSURA). Boston Properties, the developer with exclusive rights to the KSURA, owns the land, but the CRA still maintains the air rights over renovated MBTA property around Kendall station. The CRA can negotiate with Boston Properties before granting permission for construction; the terms of these transactions include development

² Cambridge, Massachusetts, Code of Ordinances §10.17.020.H

rights, infrastructure obligations, and financial considerations. Despite negotiating directly with the CRA, Boston Properties must still comply with all underlying CDD regulations and obtain city permits.

As part of the agreement to build 3 and 5 Cambridge Center, Boston Properties funded improvements to the Kendall Square station including lengthened and widened station platforms, upgraded interiors, and relocated station entrances. With the completion of the Cambridge Center buildings, Boston Properties is also obliged to operate, maintain, and repair Nowiszewski Plaza in front of the Kendall Red Line station entrance on Main Street.³

Boston Properties recently came to the CRA following Cambridge's release of the K2C2 plan in 2013 calling for one million additional square feet in the area. Negotiating with the CDD and CRA to develop one million additional square feet in the KSURA as suggested in the K2C2 plan, Boston Properties proposed that their transportation mitigation funding go almost exclusively to improving transit service on the MBTA Red Line. Tenants of the area already shirk vehicle commuting in large numbers, and private companies, including BioGen, are offering coach bus shuttles for employees from the suburbs.⁴ Boston Properties has argued that more benefits can be realized by devoting mitigation efforts to public transportation physical improvements instead of the typical TDM measures that are designed to siphon driving commuters to public transportation. The details of this arrangement and whether it may be implemented are not yet complete.

Additionally an amendment to the Kendall Square Urban Renewal Plan put forth by the CRA, a MEPA Notice of Project Change (comparable in scope to an Environmental Impact Report), was submitted to the MEPA Office to be approved in October 2015. The amendment includes elements to allow for the additional square footage and to create a transit investment tool. This amendment contains a chapter detailing the consideration of transit impacts in the MEPA process.

Chelsea

When development proposals are submitted in the city of Chelsea, a development impact statement can be requested at the discretion of the special permit granting authority. In Chelsea, most developments of a large size that would be expected to have traffic and transit impacts are done as "planned developments." These are projects that are more than two contiguous acres of

³ <http://cambridgecivic.com/?p=3491>.

⁴ <http://www.bostonglobe.com/business/2014/12/24/biogen-idec-provides-coach-commuting-for-suburban-worker/f3s5JrhADCmdD0Mae0iLoM/story.html#>.

nonresidential area or four contiguous acres of residential area, generally above 25 units, and need special permits because of their size to start construction. The required development impact statement must project the number of vehicles expected to enter and depart the site daily and at peak hours. The impact report must also show the daily volume and at peak hours on adjacent streets.

Mitigation has not traditionally been on the forefront of Chelsea's priorities for new development, but when it is done, roadway repaving, sidewalk construction, and signal improvements are the most popular measures. In the future, with the introduction of Silver Line Gateway service and interest in development growing throughout the city, city officials have more ability to ask for funding tied to local transportation improvements. New and improved pedestrian connections in the Highland Street and Central Avenue neighborhoods are likely to be addressed in the near term. Transit mitigation is unlikely at this time because the new Silver Line service will likely have sufficient capacity, and improvements to the existing bus services could well be beyond the scope of a typical mitigation agreement.

Much of the transportation mitigation done thus far with completed projects was paid for by MassWorks Infrastructure Program grants and not the developers themselves because of tightened financial markets in recent years. Chelsea has been awarded \$11.5 million in four phases since 2011 for its Gateway Center improvement in the Everett Avenue Urban Renewal District to support the development of two hotels, 250,000 square feet of office space, and 230 units of housing. Market Basket donated some land for sidewalk widening for a greenway project, and a hotel developer paid for engineering studies to redesign the Everett Avenue and Spruce Street intersection, but did not cover construction costs to implement the design changes.

Everett

Everett has not set up a redevelopment authority with appropriate powers defined by state legislation. As a consequence, Everett historically has not been able to demand transportation mitigation. Nevertheless, the city has successfully arranged for voluntary transportation improvements by developers, which largely fall under the label of limited-scale cosmetic enhancements. The Batch Yard housing developers repaved the public street in front of their complex as a means to improve its appearance and attract the luxury tenants it is targeting.

Site plan review is required for projects consisting of more than 5,000 square feet of nonresidential space or four or more residential dwelling units and should include, if requested by the planning board, a narrative addressing concerns about traffic flow and circulation. The Planning Board may also request additional studies on the adequacy of parking and loading facilities, traffic and pedestrian

circulation, and access to the site. These studies have the potential to lead to mitigation requests from the Planning Board.

In response to the potential casino siting, Everett adopted new zoning amendments that require traffic impact analyses with development proposals in particular areas of the city. A traffic impact study is required for developments in the Lower Broadway Economic Development District zone that are expected to generate more than 100 peak hour trips or more than 750 average daily trips.

This type study also must identify proposed methods as necessary to mitigate the impacts. The Planning Board, the approving authority of site plans, is allowed to accept contributions of funds to pay for the design and/or construction of off-site improvements if they are proportional to the impacts resulting from the project. The code also has performance standards for site plans that require buildings in the zone to incorporate access to water-based transportation and reduction in on-site parking if a fixed public transportation stop is within 600 linear feet of a pedestrian entrance to a project.

Much of the transportation mitigation done in Everett to date has been a result of the MEPA process. The most prominent example is the Wynn casino development, which also occasioned the proposed zoning amendments. Besides typical measures such as traffic signal improvement, sidewalk construction, and roadway redesigns to accommodate a larger vehicle volume, the Wynn casino developers proposed mitigation measures not yet employed in the Boston Core Area. The as-yet undefined, ongoing operating cost contribution to the MBTA Orange Line service to increase frequency, especially during peak hours and late-night service, and to make improvements for better handling of additional peak-hour passengers would be a first in the region. The casino operator will also run shuttle buses to connect with Malden Center and Wellington MBTA stations, and may construct a pedestrian bridge over the Mystic River to Assembly Square station. Wynn also proposes funding long-term Sullivan Square mitigation projects for 10 years after the project opens and to pay the city of Boston for every vehicle above Friday PM peak period projections.⁵

A study underway by MassDOT, the Everett Transit Action Plan, envisions a set of smaller-scale recommendations. These could either be implemented through future mitigation agreements or possibly implemented by the city itself.

⁵ <https://www.bostonglobe.com/business/2015/07/30/wynn-aims-first-company-subsidize-mbta-operations-with-orange-line-plans/bzl3fNIPbSBzBsogXDYpsI/story.html>.

Medford

In Medford, transportation mitigation measures are identified regularly during site plan review for all residential projects of six or more units, all commercial projects over 10,000 square feet, all medical office space of 5,000 or more square feet, or all restaurant projects over 2,500 square feet. Traffic analyses included in the written statement of site plan applications must estimate peak-hour traffic volumes generated by the proposed use in relation to exiting volumes and projected future conditions.

Based on their expected impact, each project's mitigation requirements are negotiated on a case-by-case basis, but where multiple projects are proposed for the same area, it is often the first project to be approved that is responsible for the desired roadway improvements in the project area. The mitigation measure most often required for approval is retiming traffic signals, but sidewalk improvements, roadway widening, curb-cut access, and pedestrian connections are also frequent.

Additionally, a linkage fee based on the size of a project is assessed across the entire town regardless of development site and contributes to a fund responsible for local roadway and traffic facility capital improvement projects with linkage grants to the parks and recreation facilities trust.⁶

Revere

Because much of the residential and commercial development occurring in the city of Revere falls along state-owned roadways near the shoreline, the city relies largely on MassDOT to develop transportation mitigation policies on a case-by-case basis through its State Highway Access Permits procedures. The requirements and process of MassDOT review are described later in this section.

Despite MassDOT's extensive involvement in transportation mitigation in Revere, site plan review regulations allow Revere to request traffic impact studies from multifamily, commercial, and industrial projects. These studies must detail:

- Existing traffic volume, composition, peak hour levels, and existing street capacities
- Estimated average daily traffic generation, composition peak hour levels, and directional flows resulting from the proposed development
- Proposed methods to mitigate the estimated traffic impact
- Methodology and sources used to derive existing data and estimations.⁷

⁶ Ord. No. 548 §17 c-1, 4-3-1990

⁷ Revere, Massachusetts, Code of Ordinances, 90-237 § 1 (part)

The site plan review committee considers the convenience and safety of vehicular and pedestrian movement as well as access configuration in relation to adjacent streets when making recommendations about approval.

Funding for many mitigation projects, including roadway reconfiguration, Blue Line station platform extensions, signalization improvement, and bus-stop consolidations, has come from the federal government, the state government, or the MBTA. Individual developers do not routinely contribute. Revere maintains a mechanism for this to become a more common practice, however. The Community Improvement Trust Fund is a separate fund through which funds can be directed to specific projects by the mayor with approval of the City Council.

Payments to the fund come from projects that have been granted special permits or variances above the intensity of use written into the zoning code, where the amount is proportional to the portion of the project that exceeds the code regulations. Payments to the trust are to be made in two equal installments up to a maximum of three percent of total construction costs, the first payment made at the issuance of a building permit and the second made at the issuance of an occupancy permit. The funds may be expended on more than just transportation facilities, but must be appropriated to facilities directly impacted by the project. The possible infrastructure and community facilities eligible for funding include:

- Roadway and sidewalk reconstruction
- Signalization improvements
- Sewer, water, and drainage improvements
- Recreation and open space areas and the support of athletic programs
- Fire protection facilities and equipment
- Crime prevention facilities and equipment
- School buildings and educational programs
- Library improvements⁸

Somerville

Somerville, like many other communities in the Study Area, determines its required transportation mitigation measures by negotiating with developers on a case-by-case basis. Nonetheless, the plan review process almost always includes some form of impact evaluation, even if mitigation is not required thereafter. For projects necessitating special permits, Planned Unit Developments (PUD), and Preliminary Master Plans, detailed explanations of any changes to the vehicular, bicycle, and pedestrian circulation patterns is required as an application supplementary form for the Planning Board before approval can be granted.

⁸ Revere, Massachusetts, Code of Ordinances, 91-23 § 8 (part)

The Special Districts proposed in the draft 2015 Zoning Ordinance update have additional traffic impact reviews. Any already approved PUD is to be considered a Neighborhood Development Plan and remain in effect, but future special approval processes are shown in Table 27. When applicable, the Planning Board may also request a Transportation Study, a Traffic Access and Impact Study, and/or a Transportation Demand Management Plan in the Assembly Square special zoning district, which will be reviewed by the Director of Traffic and Parking.

There are some design elements included in the draft 2015 Zoning Ordinance update currently under review that incorporate public realm requirements to promote pedestrian activity, such as required sidewalk widths in some residential mixed-use districts. In Somerville, all nonresidential uses with more than 5,000 square feet of gross leasable space are required to provide bicycle parking in amounts specified in the zoning code for each principal use category.

Table 27
Somerville Neighborhood Requirements for Plan Approval Process

Special District	Large Development Plan Approval	Neighborhood Development Plan Approval
Assembly Square	5+ acres	40+ acres
Brickbottom	2+ acres	20+ acres
Grand Junction		10+ acres
Inner Belt	8+ acres	20+ acres

Source: Somerville Zoning Ordinance, January 22, 2015 BOA Submittal

MassDOT

MassDOT gets involved with a development's transportation mitigation measures in two ways: 1) MEPA regulations and 2) Approvals of Access to State Highways with Section 61 Findings. Preparation of a Transportation Impact Assessment (TIA) is triggered by MEPA thresholds—generally more than 3,000 new average daily trips to a single location or the addition of 1,000 or more parking spaces at a single location—and/or by the MassDOT state highway access regulations. Projects that are on state highways, or whose trip generation will impact nearby state highways or intersections controlled by MassDOT, are subject to access approval procedures.⁹

⁹ http://www.massdot.state.ma.us/Portals/8/docs/access_permits/HMD_60_02_3_000.pdf.

For TIA scoping purposes, MassDOT requires the preparation of a Transportation Scoping Letter (TSL) that agrees on the analytical approach, technical assumptions, and key issues to be addressed. TSLs must be submitted early in the development process, no later than the Environmental Notification Form, and are considered preliminary and likely to evolve throughout the process. The TSL, nevertheless, must include the following elements:

- Projected trip generation
- Mode split
- Transportation demand management measures adopted
- Study area and transportation network
- Trip distribution pattern
- Analysis periods
- Site plans
- Access spacing and circulation assessment
- Safety
- Parking

Guidelines for the TIA provide for a multimodal transportation development review to enhance transit, bicycle, and pedestrian facilities and to emphasize transportation-efficient development. They also foster implementation of TDM programs. In particular, calculations for transit ridership by direction and by route, dwell times, crowding, speeds, and multimodal level-of-service changes from pre- and post-development scenarios must be included. TIA information ensures that mitigation measures are fully funded with descriptions of responsible parties, timelines to completion, and duration of responsibility. The TIA also provides the basis for ongoing monitoring programs to evaluate the effectiveness of mitigation measures.¹⁰

The finished TIA, completed through consultation and negotiation between all stakeholders, provides the developer, affected municipalities, MassDOT, MassRIDES, local TMA, and the general public with information needed to assess the adequacy of existing and planned transportation infrastructure, the project's impacts, and proposed mitigation measures. MassDOT has the prerogative to accept financial payment in lieu of direct investment in mitigation facilities and/or service improvements, at its discretion, which would be deposited in a mitigation bank to fund future improvements.

State Highway Access Permits are issued by the MassDOT Highway Division. Section 61 Findings, if applicable based on the Final EIR, identify multimodal mitigation measures to balance the needs of all users of the transportation

¹⁰ <http://www.mass.gov/eea/docs/mepa/transportation-impact-assessment-guidelines-3-13-14.pdf>

network. TDM programs are frequently a component of access permits. Physical actions must be settled by the time of approval, whereas nonphysical actions must be available upon site opening. On-site physical mitigation examples include configuration of driveway design, building arrangement, parking management, internal circulation, and pedestrian, bicycle, and transit accommodations. Off-site mitigation measures can include traffic signal coordination and/or optimization, intersection reconstruction, roadway widening, transit service improvements, bus priority signal systems, and access management.

MBTA

The MBTA has very little history of engaging in mitigation negotiations with developers, in part because of limited legal authority and jurisdiction. As a result, there is also no standard protocol for involving private developers with transit mitigation. When offering bids for transit-oriented development on MBTA property, the statute requires disposing of land or entering into a ground lease with the “highest responsive bidder” that offers the most financial value to the MBTA and that also meets certain nonfinancial requirements such as a history of and references for competent project management as well as a record of successful projects. Projects near MBTA stations but not on MBTA land have no obligation to involve the MBTA in transportation mitigation negotiations.

The Wynn casino project in Everett is the largest project to date that the MBTA has actively engaged in discussions about transit impacts based on new trips generated. The mitigation measures to be implemented are not yet finalized, but potentially include operational subsidies as well as a number of physical construction projects designed to improve circulation and efficiency at nearby rapid transit and commuter rail stations related to both train and bus service.

The proposed Boston Landing/New Balance commuter rail station is another example in which a private developer contributes significant funds to the MBTA. In contrast to the Wynn Casino’s use of existing stations and improvement of circulation and transit service, the new infill commuter rail station will be financed privately by New Balance. New Balance will also commit to covering station maintenance costs for several years in exchange for two guaranteed peak period trains stopping in each direction on weekdays.

The Assembly Square Orange Line station was partially financed by Federal Realty Investment Trust, the developer that also developed the adjacent transit-oriented Assembly Row complex. The MBTA is in the process of beginning a conversation about transportation mitigation with another private developer desiring to construct more square footage in the area.

Much greater participation in the development process, and therefore the ability to negotiate mitigation, may be possible for transit-oriented projects constructed on MBTA land. The MBTA Real Estate Department oversees the agency's real estate holdings and manages its office and warehouse facilities. Massachusetts Realty Group, the MBTA's asset manager, manages the leasing, licensing, inventory, easements, sale of MBTA property, and air rights holdings. One such project is the air rights development over the Hynes Convention Center station, which will involve an MBTA Station Improvements Agreement to renovate the Green Line station to be accessible to people with disabilities and to refurbish a second station entrance. This, as is typical of other joint development projects the MBTA has done, will involve the developer funding design and construction costs of station improvements, but the MBTA actually administering the work.